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TITLE: Antimicrobial peptides, useful for prevention and treatment of periodontal disease

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<u>AU 9913272 A</u>	June 15, 1999	EN
<u>ZA 9810679 A</u>	October 27, 1999	EN
<u>EP 1032592</u>	September 6, 2000	EN
<u>A1</u>		
<u>JP 2002503641 W</u>	February 5, 2002	JA
<u>AU 756347 B</u>	January 9, 2003	EN
<u>US 20030195150</u>	October 16, 2003	EN
<u>A1</u>		
<u>EP 1032592</u>	July 25, 2007	EN
<u>B1</u>		
<u>DE 69838143 E</u>	September 6, 2007	DE
<u>DE 69838143 T2</u>	April 10, 2008	DE
<u>US 7588752 B2</u>	September 15, 2009	EN

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ZA 9810679A	November 23, 1998	1998ZA-010679	
DE 69838143E	November 24, 1998	1998DE-638143	
DE 69838143T2	November 24, 1998	1998DE-638143	
EP 1032592A1	November 24, 1998	1998EP-956720	
EP 1032592B1	November 24, 1998	1998EP-956720	
EP 1032592A1	November 24, 1998	1998WO-AU00972	
JP2002503641W	November 24, 1998	1998WO-AU00972	
EP 1032592B1	November 24, 1998	1998WO-AU00972	
DE 69838143E	November 24, 1998	1998WO-AU00972	
DE 69838143T2	November 24, 1998	1998WO-AU00972	
AU 9913272A	November 24, 1998	1999AU-013272	
AU 756347B	November 24, 1998	1999AU-013272	
JP2002503641W	November 24, 1998	2000JP-522127	
US20030195150A1	October 24, 2002	2002US-280833	
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CIPS	<u>A23 J 3/10</u>	20060101
CIPS	<u>A61 K 35/20</u>	20060101
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CIPS	<u>A61 K 38/17</u>	20060101
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CIPP C07 K 14/47 20060101
CIPS C07 K 14/78 20060101

ABSTRACTED-PUB-NO: WO 9926971 A1

BASIC-ABSTRACT:

NOVELTY - Non-glycosylated antimicrobial peptide is new.

DESCRIPTION - New non-glycosylated antimicrobial peptide of less than 100 amino acids (aa) is selected from four 21 aa peptides (I-IV), and one 19 aa peptide (V) sequences, and (I-V) having conservative substitutions.

INDEPENDENT CLAIM is also included for a chimeric compound including the above peptide conjugated to a non-peptide molecule.

USE - The peptide is useful in antimicrobial compositions for treating or preventing dental caries or periodontal disease (claimed).

ADVANTAGE - The new peptides are clinically efficacious, safe and natural antiplaque agents, unlike prior art agents which have undesirable side-effects, negligible intra-oral activity, or an incompatibility with toothpaste formulations.

ABSTRACTED-PUB-NO: WO 9926971 A1

EQUIVALENT-ABSTRACTS:

BIOLOGY

Preferred Peptides: The peptides (I)-(V) preferably have the defined sequences and are less than 70 amino acids. The peptides preferably include 12 fully defined peptide sequences (given in the specification), e.g.

MAIPPKKNQDKTEIPTINTIASGEPTSTPTIEAVESTVATLEASIGMAPEVIESPPEINTVQVTSTAV.

Preferred Compound: The non-peptide portion of the molecule includes acyl groups.

Preparation: The peptides are preferably obtained from milk protein casein.

BIOTECHNOLOGY

Preparation: The peptides can be prepared using standard recombinant technology.

ORGANIC CHEMISTRY

Preparation: The peptides can be chemically synthesized.

Administration is to the teeth or gums (claimed), as a gel, liquid, solid, powder, cream or lozenge. The peptides comprise 0.01-50 (preferably 0.1-10)% by

weight of the composition.

SPECIFIC PEPTIDES

The peptides have the following sequences:

AVESTVATLEASIGMAPEVIESPPE (I)

AVESTVATLED SIGMAPEVIESPPE (II)

AVESTVATLEASPEVIESPPE (III)

AVESTATLED SPEVIESPPE (IV)

DMPIQAFLLYQQPVLPV (V)

MAIPPKKNQDKTEIPTINTIASGEPTSTPTIEAVESTVATLEASIGMAPEVIESPPEINTVQVTSTAV (VI)

MAIPPKKNQDKTEIPTINTIASIGMAGEPTSTPTIEAVESTVATLEASIGMAPEVIESPPEINTVQVTSTAV (VII)

MAIPPKKNQDKTEIPTINTIASGEIPTSTPTTEAVESTVATLEDSIGMAPEVIESPPEINTVQVTSTAV (VIII)

MAIPPKKNQDKTEIPTINTIASIGMAGEPTSTPTTEAVESTVATLEDSIGMAPEVIESPPEINTVQVTSTAV (IX)

TEIPTINTIASGEPTSTPTIEAVESTVATLEASIGMAPEVIESPPEINTVQVTSTAV (X)

TEIPTINTIASIGMAGEPTSTPTIEAVESTVATLEASIGMAPEVIESPPEINTVQVTSTAV (XI)

TEIPTINTIASGEPTSTPTTEAVESTVATLEDSIGMAPEVIESPPEINTVQVTSTAV (XII)

TEIPTINTIASIGMAGEPTSTPTTEAVESTVATLEDSIGMAPEVIESPPEINTVQVTSTAV (XIII)

MAIPPKKNQDKTEIPTINTIASGEPTSTPTIEAVESTVATLEASPEVIESPPEINTVQVTSTAV (XIV)

MAIPPKKNQDKTEIPTINTIASGEPTSTPTTEAVESTVATLEASPEVIESPPEINTV QVTSTAV (XV)

TEIPTINTIASGEPTSTPTIEAVESTVATLEASPEVIESPPEINTVQVTSTAV (XVI)

TEIPTINTIASGEPTSTPTFEAVESTVATLEDSPEVIESPPEINTVQVTSTAV (XVII)

Cheese whey was ultrafiltered through a 20 kDa molecular weight cut off membrane. The filtrate was collected and proteins precipitated by addition of TCA to a final concentration of 11 % w/v. The proteins were removed by centrifugation and were lyophilised and dissolved in 0.1 % TFA in water, and subjected to RP-HPLC. The sample was applied to the Brownlee analytical column and eluted. Fractions were assayed for antibacterial activity using sterile 96 well plates. Each well had 250 microl media containing the peptide in varying concentrations, and were inoculated with 50 microl bacteria inoculum. Growth of bacteria was determined using OD. Mass spectrometric analysis (MS) of the peptides was performed and two gel filtration peaks with the same specific antimicrobial activity contained the same peptides.

DERWENT-CLASS: B04 D16 D21

CPI-CODES: B04-C01D; B04-C01E; B04-C01G; B04-N04A; B14-A01; B14-N06; D05-C02; D05-H12A; D05-H12C; D05-H17C; D08-A05;

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(54) Title: ANTIMICROBIAL PEPTIDES**(57) Abstract**

The present invention provides antimicrobial peptides. The peptides are non-glycosylated, less than about 100 amino acids and include an amino acid sequence selected from the group consisting of: AVESTVATLEA Σ PEVIESPPE (SEQ. ID. NO. 1), AVESTVATLED Σ PEVIESPPE (SEQ. ID. NO. 2), AVESTVATLEASPEVIESPPE (SEQ. ID. NO. 3), AVESTVATLEDSPEVIESPPE (SEQ. ID. NO. 4), DMPIQAFLLYQQPVLPVVR (SEQ. ID. NO. 5), and conservative substitutions therein. These peptides can be produced synthetically, however, they can most conveniently be derived from casein.

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EE	Estonia						

*Antimicrobial Peptides***FIELD OF THE INVENTION**

5 The present invention relates to novel antimicrobial peptides which can be obtained from the milk protein casein or chemically synthesised or produced by recombinant DNA technology. These peptides can be used in foods as antimicrobial preservatives, in oral care products (eg. toothpaste, mouthwash, dental floss) for the control of dental plaque and suppression of
10 pathogens associated with dental caries and periodontal diseases. The antimicrobial peptides may also be used in pharmaceutical preparations for topical or parenteral application or oral administration for the control of oro-pharangeal and gastro-intestinal pathogens as well as systemic or localised infections.

15

BACKGROUND OF THE INVENTION

Periodontal diseases are bacterial-associated inflammatory diseases of the supporting tissues of the teeth and are a major public health problem.
20 Nearly all of the human population is affected by periodontal diseases to some degree. In a recent Melbourne survey (Spencer *et al.*, 1985) only 20% of the adult dentate sample did not require periodontal treatment while 62% required intermediate treatment and 18% required complex treatment. Brown *et al.* (1989), from an extensive US Dental Health survey reported that
25 only 15% of the studied population was free of periodontal diseases. The major form of periodontal disease is gingivitis which is associated with the non-specific accumulation of dental plaque at the gingival margin. In contrast, the less prevalent, destructive form of periodontal disease (periodontitis) is associated with a subgingival infection of specific
30 Gram-negative bacteria. Periodontitis is a major cause of tooth loss in Australian adults.

Although gingivitis may not be a necessary precondition for the development of periodontitis (Christersson *et al.*, 1989) gingivitis is likely to predispose susceptible sites to more serious forms of periodontal disease
35 since the specific Gram-negative bacteria that predominate in periodontitis, but which are not detectable in the healthy periodontium, have been found

in low proportions in gingivitis (Moore *et al.*, 1987). Further, the environmental conditions that develop during gingivitis are likely to favour the subsequent colonisation or growth of the species implicated in periodontitis. The control of supragingival plaque is therefore considered an important part of a preventive strategy for the control of periodontal diseases and in fact various plaque control programs have proven to be successful in the prevention of periodontal diseases (Loesche, 1976). In the majority of individuals the customary oral hygiene method of toothbrushing is usually insufficient by itself over long periods to provide a level of plaque control compatible with oral health. Consequently the incorporation of antimicrobial agents into dental products as an aid to controlling dental plaque and gingivitis has been advocated (Addy, 1988; Marsh, 1991) and is of considerable interest to toothpaste and mouthwash companies. A number of agents have been suggested as antiplaque toothpaste additives (eg. bisbiguanides, phenols, metal ions, quaternary ammonium salts) but have either negligible intra-oral activity, undesirable side-effects (eg. mucosal irritation, tooth discolouration) and/or an incompatibility with toothpaste formulations. Triclosan (2,4,4'-trichloro-2'-hydroxy diphenyl ether) an antimicrobial agent used extensively in deodorants, soaps and other dermatological preparations is currently being used as an anti-plaque toothpaste additive in some countries however there is considerable interest to find a clinically efficacious, safe and natural antiplaque agent.

Antimicrobial peptides are widely distributed in nature and play a role in the host defence of plants and animals (Boman and Hultmark, 1987; Bevins and Zasloff, 1990). They include amongst others, the amphipathic channel forming peptides, for example the cecropins isolated from the cecropia moth (Boman and Hultmark, 1987), the magainins isolated from skin secretions of the African clawed frog *Xenopus laevis* (Bevins and Zasloff, 1990), the dermaseptins isolated from the skin of the arboreal frog (Mor and Nicolas, 1994) and the bombinins from the skin of *Bombina variegata* (Simmaco *et al.*, 1991). Other antimicrobial peptides include the cyclic cationic peptides containing an intramolecular disulphide, for example ranalexin from bullfrog skin (Clark *et al.*, 1994) and bactenecin from bovine neutrophils (Romeo *et al.*, 1988). Proline-containing antimicrobial peptides also have been identified and these include the apidaecins from the lymph

fluid of the honeybee (Casteels *et al.*, 1989) and the pig myeloid antimicrobial peptide PMAP-23 (Zanetti *et al.*, 1994).

It is now well established that the milk protein casein should be considered not only as a nutrient but also as a protecting agent against bacterial infection of the neonate mucosa as specific peptides released by tryptic or *in situ* digestion have been shown to possess marked biological activity. These bioactive peptides are relatively resistant to further proteolytic breakdown and have been detected in the distal portion of the small intestine and blood of humans after ingestion of cow's milk (Svedberg *et al.*, 1985). Migliore-Samour *et al.* (1989) have shown that peptides β -casein(63-68) PGPIP and α_{s1} -casein(194-199) TTMPLW at concentrations as low as 0.1 μ M exert a significant protective effect in mice against *Klebsiella pneumoniae* infection when injected intravenously at 0.3 mg/kg, before lethal infectious challenge. An antibacterial peptide from bovine α_{s2} -casein [α_{s2} -casein (f172-203)] released by treatment of milk with glacial acetic acid has recently been characterised and shown to inhibit the growth of *Escherichia coli* and *Staphylococcus carnosus* (Zucht *et al.*, 1995).

Antimicrobial peptides having activity against a range of Gram-positive and Gram-negative bacteria have potential in the area of oral care, functional foods, food preservatives and pharmaceuticals. Oral care products include toothpaste, mouthwash, dental floss and professionally applied materials. Functional foods include chewing gum, confectionery, breakfast cereals, infant formula, beverages, lozenges etc. Food preservatives application could include dairy products, soups, salad dressings, processed meats, baked goods, sauces etc. Pharmaceutical use would include systemic and topically applied antibiotics and anti-infectives and medications for the treatment of ulcers and other gastro-intestinal tract diseases.

For food applications, natural antimicrobials are typically used for the maintenance and extension of shelf-life in sauces, wet salads, baked goods and pastries, processed meats, refrigerated dairy products, salad dressings and soaps. Nisin has limited application as a food preservative due to a relatively narrow spectrum of antimicrobial activity and high cost. Food manufacturers using casein antimicrobial peptides as a preservative may use "all natural" label claims which are not allowed when using artificial or chemical preservatives. A major trend in the food industry is the increasing demand for low fat products which in general tend to have increased

moisture levels. This creates a demand for better food preservation systems such as the incorporation of natural antimicrobials.

The global market for medications for wound healing, treatment of upper gut ulcers and inflammatory based disease represents a major pharmaceutical market. Clinicians working in the area of duodenal and gastric ulcers currently focus on the bacterium *Helicobacter pylori* as the causative agent in upper gut ulcers. Channel forming antimicrobial peptides that allow H⁺ to enter the bacterial cell have the potential for treatment of *H. pylori* infections by enhancing the sensitivity of the bacterium to the acid secretions of the stomach.

SUMMARY OF THE INVENTION

The present inventors have developed new peptides which have antimicrobial activity. These peptides can be produced synthetically, however, they can most conveniently be derived from casein.

Accordingly, in a first aspect the present invention consists in an antimicrobial peptide, the peptide being non-glycosylated, less than about 100 amino acids, preferably less than about 70 amino acids, and including an amino acid sequence selected from the group consisting of:-

AVESTVATLEA Σ PEVIESPPE,
AVESTVATLED Σ PEVIESPPE,
AVESTVATLEASPEVIESPPE,
AVESTVATLEDSPPEVIESPPE,
25 DMPIQAFLLYQQPVLPVR,

and conservative substitutions therein.

In a preferred embodiment of the present invention the peptide includes an amino acid sequence selected from the group consisting of:-

AVESTVATLEA Σ PEVIESPPE, AVESTVATLED Σ PEVIESPPE,
30 AVESTVATLEASPEVIESPPE, AVESTVATLEDSPPEVIESPPE, and
DMPIQAFLLYQQPVLPVR, preferably AVESTVATLEA Σ PEVIESPPE,
AVESTVATLED Σ PEVIESPPE, or DMPIQAFLLYQQPVLPVR.

In a further preferred embodiment of the present invention the peptide includes an amino acid sequence selected from the group consisting of:-

MAIPPKKNQDKTEIPTINTIASGEPTSTPTIEAVESTVATLEAΣPEVIESPPEINT
5 VQVTSTAV;
MAIPPKKNQDKTEIPTINTIAΣGEPTSTPTIEAVESTVATLEAΣPEVIESPPEINT
VQVTSTAV;
MAIPPKKNQDKTEIPTINTIASGEPTSTPTTEAVESTVATLEDΣPEVIESPPEINT
VQVTSTAV;
10 MAIPPKKNQDKTEIPTINTIAΣGEPTSTPTTEAVESTVATLEDΣPEVIESPPEINT
VQVTSTAV;
TEIPTINTIASGEPTSTPTIEAVESTVATLEAΣPEVIESPPEINTVQVTSTAV;
TEIPTINTIAΣGEPTSTPTIEAVESTVATLEAΣPEVIESPPEINTVQVTSTAV;
TEIPTINTIASGEPTSTPTTEAVESTVATLEDΣPEVIESPPEINTVQVTSTAV;
15 TEIPTINTIAΣGEPTSTPTTEAVESTVATLEDΣPEVIESPPEINTVQVTSTAV;
MAIPPKKNQDKTEIPTINTIASGEPTSTPTIEAVESTVATLEASPEVIESPPEINT
VQVTSTAV;
MAIPPKKNQDKTEIPTINTIASGEPTSTPTTEAVESTVATLEDSPEVIESPPEINT
VQVTSTAV;
20 TEIPTINTIASGEPTSTPTIEAVESTVATLEASPEVIESPPEINTVQVTSTAV;
TEIPTINTIASGEPTSTPTTEAVESTVATLEDSPEVIESPPEINTVQVTSTAV;
and conservative substitutions therein.

It is further preferred that the peptide includes an amino acid sequence selected from the group consisting of:-

25 MAIPPKKNQDKTEIPTINTIASGEPTSTPTIEAVESTVATLEAΣPEVIESPPEINT
VQVTSTAV;
MAIPPKKNQDKTEIPTINTIAΣGEPTSTPTIEAVESTVATLEAΣPEVIESPPEINT
VQVTSTAV;
MAIPPKKNQDKTEIPTINTIASGEPTSTPTTEAVESTVATLEDΣPEVIESPPEINT
30 VQVTSTAV;
MAIPPKKNQDKTEIPTINTIAΣGEPTSTPTTEAVESTVATLEDΣPEVIESPPEINT
VQVTSTAV;
TEIPTINTIASGEPTSTPTIEAVESTVATLEAΣPEVIESPPEINTVQVTSTAV;
TEIPTINTIAΣGEPTSTPTIEAVESTVATLEAΣPEVIESPPEINTVQVTSTAV;
35 TEIPTINTIASGEPTSTPTTEAVESTVATLEDΣPEVIESPPEINTVQVTSTAV;
TEIPTINTIAΣGEPTSTPTTEAVESTVATLEDΣPEVIESPPEINTVQVTSTAV;

MAIPPKKNQDKTEIPTINTIASGEPTSTPTIEAVESTVATLEASPEVIESPPEINT
VQVTSTAV;

MAIPPKKNQDKTEIPTINTIASGEPTSTPTTEAVESTVATLEDSPPEINT
VQVTSTAV;

5 TEIPTINTIASGEPTSTPTIEAVESTVATLEASPEVIESPPEINTVQVTSTAV; and
TEIPTINTIASGEPTSTPTTEAVESTVATLEDSPPEINTVQVTSTAV.

In yet a further preferred embodiment of the present invention the peptide is selected from the group consisting of:-

MAIPPKKNQDKTEIPTINTIASGEPTSTPTIEAVESTVATLEA Σ PEVIESPPEINT
10 VQVTSTAV;

MAIPPKKNQDKTEIPTINTIA Σ GEPTSTPTIEAVESTVATLEA Σ PEVIESPPEINT
VQVTSTAV;

MAIPPKKNQDKTEIPTINTIASGEPTSTPTTEAVESTVATLED Σ PEVIESPPEINT
VQVTSTAV;

15 MAIPPKKNQDKTEIPTINTIA Σ GEPTSTPTTEAVESTVATLED Σ PEVIESPPEINT
VQVTSTAV;

TEIPTINTIASGEPTSTPTIEAVESTVATLEA Σ PEVIESPPEINTVQVTSTAV;
TEIPTINTIA Σ GEPTSTPTIEAVESTVATLEA Σ PEVIESPPEINTVQVTSTAV;
TEIPTINTIASGEPTSTPTTEAVESTVATLED Σ PEVIESPPEINTVQVTSTAV;

20 20 TEIPTINTIA Σ GEPTSTPTTEAVESTVATLED Σ PEVIESPPEINTVQVTSTAV;
AVESTVATLEA Σ PEVIESPP;
AVESTVATLED Σ PEVIESPP;
MAIPPKKNQDKTEIPTINTIASGEPTSTPTIEAVESTVATLEASPEVIESPPEINT
VQVTSTAV;

25 MAIPPKKNQDKTEIPTINTIASGEPTSTPTTEAVESTVATLEDSPPEINT
VQVTSTAV;

TEIPTINTIASGEPTSTPTIEAVESTVATLEASPEVIESPPEINTVQVTSTAV;
TEIPTINTIASGEPTSTPTTEAVESTVATLEDSPPEINTVQVTSTAV;
AVESTVATLEASPEVIESPP;

30 30 AVESTVATLEDSPPEINTVQVTSTAV;
DMPIQAFLLYQQPVVLGPVR.

As will be understood by those skilled in this field the peptide of the present invention can be conjugated to other molecules, such as acyl derivatives, to alter the delivery profile or pharmacokinetics of the peptide.

35 Such conjugates are described in PCT/AU90/00599, the disclosure of which is incorporated herein by reference.

In a second aspect the present invention consists in a chimeric compound, the compound including the peptide of the first aspect of the present invention conjugated to a non-peptide molecule. It is preferred that the non-peptide molecule includes acyl groups.

5 In a third aspect the invention provides an antimicrobial compositions including the peptide of the first aspect of the present invention together with a pharmaceutically-acceptable carrier. Such compositions may be dental, intra-oral compositions, therapeutic anti-infective compositions for topical and systemic application. Dental
10 compositions or therapeutic compositions may be in the form of a gel, liquid, solid, powder, cream or lozenge. Therapeutic compositions may also be in the form of tablets or capsules.

In a fourth aspect, there is provided a method of treating or preventing dental caries or periodontal disease in a subject, the method
15 comprising the step of administering a peptide or composition of the present invention to the teeth or gums of a subject in need of such treatments.
Topical administration of the peptide is preferred.

Without wishing to be bound by scientific theory it is believed that the peptides of the present invention exert their antimicrobial activity by
20 virtue of their amphipathic nature. It is believed that the peptides are incorporated into the bacterial membrane where they form aggregates. These aggregates provide or form pores or channels through the membrane through which ions may pass. The uncontrolled passage of ions across the bacterial membrane results in the death of the bacterial cell.

25 As it is the physical nature of the peptides rather than the specific sequence of the peptide which results in their antimicrobial activity so called conservative substitutions may be made in the peptide sequence with no substantial loss of activity. It is intended that such conservative substitutions which do not result in a substantial loss of activity are
30 encompassed in the present invention.

Whilst the concept of conservative substitution is well understood by the person skilled in the art, for the sake of clarity conservative substitutions are those set out below.

- G, A, V, I, L, M;
- 5 D, E, S;
- N, Q;
- S, T;
- K, R, H;
- F, Y, W, H; and
- 10 P, N α -alkalamino acids.

Where Σ is a phosphoseryl residue.

The peptides of the present invention have a number of applications, for example, they can be used in foods as antimicrobial preservatives, in oral care products (toothpastes and mouthrinses) for the control of dental plaque and suppression of pathogens associated with dental caries and periodontal diseases. The antimicrobial peptides of the present invention may also be used in pharmaceutical preparations (eg, topical and systemic anti-infective medicines).

Throughout this specification the word "comprise", or variations such as "comprises" or "comprising", will be understood to imply the inclusion of a stated element or integer or group of elements or integers but not the exclusion of any other element or integer or group of elements or integers.

DETAILED DESCRIPTION OF THE INVENTION

25

The present invention relates to the novel antimicrobial peptides. These peptides were initially derived from casein, κ -casein (106-169) and β -casein (184-202) [Table 1]. These peptides have potential to be used for the following micro-organisms *inter alia*.

- 30 *Streptococcus mutans*
- Staphylococcus aureus*
- Streptococcus sanguinis*
- Escherichia coli*
- Salmonella typhimurium*
- 35 *Pseudomonas aeruginosa*
- Porphyromonas gingivalis*

Campylobacter jejuni
Listeria monocytogenes
Helicobacter pylori
Clostridium botulinum
5 *Streptococcus pyogenes*
Streptococcus pneumoniae
Candida albicans

The antimicrobial peptides Ser(*P*)¹⁴⁹ κ-casein B (106-169) and
10 Ser(*P*)¹⁴⁹ κ-casein B (117-169) both had a minimum inhibitory concentration
(MIC) of 2.4 μM against the oral pathogens *Streptococcus mutans* and
Streptococcus sobrinus and at a ten-fold lower concentration (0.24μM)
inhibited growth of these bacteria by 41%.

The antimicrobial peptides Ser(*P*)¹⁴⁹ κ-casein (117-169) and Ser(*P*)¹²⁷,
15 Ser(*P*)¹⁴⁹ κ-casein (117-169) and β-casein (184-202) can be purified from a
tryptic digest of bovine casein using standard chromatographic procedures of
anion exchange and reversed-phase chromatography (HPLC). Ser(*P*)¹⁴⁹
κ-casein (106-169) and Ser(*P*)¹²⁷, Ser(*P*)¹⁴⁹ κ-casein (106-169) can also be
prepared from cheese whey and rennet whey by removal of the whey
20 proteins by ultrafiltration, or acid precipitation followed by reversed-phase
HPLC purification of the phosphopeptides. The peptides can be prepared
from casein of other species, eg. goat, sheep etc.

Table 1. Casein Antimicrobial Peptides

Peptide	Sequence ^a
Ser(<i>P</i>) ¹⁴⁹ κ-casein B (106-169)	MAIPPKKNQDKTEIPTINTIASGEPTSTPTIEAVESTVA TLEAΣPEVIESPPEINTVQVTSTAV
Ser(<i>P</i>) ¹²⁷ , Ser(<i>P</i>) ¹⁴⁹ κ-casein B (106-169)	MAIPPKKNQDKTEIPTINTIAΣGEPTSTPTIEAVESTVA TLEAΣPEVIESPPEINTVQVTSTAV
Ser(<i>P</i>) ¹⁴⁹ , κ-casein A (106-169)	MAIPPKKNQDKTEIPTINTIASGEPTSTPTTEAVESTVA TLEDΣPEVIESPPEINTVQVTSTAV
Ser(<i>P</i>) ¹²⁷ , Ser(<i>P</i>) ¹⁴⁹ κ-casein A (106-169)	MAIPPKKNQDKTEIPTINTIAΣGEPTSTPTTEAVESTV ATLEDΣPEVIESPPEINTVQVTSTAV
Ser(<i>P</i>) ¹⁴⁹ κ-casein B (117-169)	TEIPTINTIASGEPTSTPTIEAVESTVATLEAΣPEVIESPP EINTVQVTSTAV
Ser(<i>P</i>) ¹²⁷ , Ser(<i>P</i>) ¹⁴⁹ κ-casein B (117-169)	TEIPTINTIAΣGEPTSTPTIEAVESTVATLEAΣPEVIESP PEINTVQVTSTAV
Ser(<i>P</i>) ¹⁴⁹ κ-casein A (117-169)	TEIPTINTIASGEPTSTPTTEAVESTVATLEDΣPEVIESP PEINTVQVTSTAV
Ser(<i>P</i>) ¹²⁷ , Ser(<i>P</i>) ¹⁴⁹ κ-casein A (117-169)	TEIPTINTIAΣGEPTSTPTTEAVESTVATLEDΣPEVIESP PEINTVQVTSTAV
Ser(<i>P</i>) ¹⁴⁹ κ-casein B (138-158)	AVESTVATLEAΣPEVIESPP
Ser(<i>P</i>) ¹⁴⁹ κ-casein A (138-158)	AVESTVATLEDΣPEVIESPP
κ-casein B (106-169)	MAIPPKKNQDKTEIPTINTIASGEPTSTPTIEAVESTVA TLEASPEVIESPPEINTVQVTSTAV
κ-casein A (106-169)	MAIPPKKNQDKTEIPTINTIASGEPTSTPTTEAVESTVA TLEDSPEVIESPPEINTVQVTSTAV
κ-casein B (117-169)	TEIPTINTIASGEPTSTPTIEAVESTVATLEASPEVIESPP EINTVQVTSTAV
κ-casein A (117-169)	TEIPTINTIASGEPTSTPTTEAVESTVATLEDSPEVIESP PEINTVQVTSTAV
κ-casein B (138-158)	AVESTVATLEASPEVIESPP
κ-casein A (138-158)	AVESTVATLEASPEVIESPP
β-casein (184-202)	DMPIQAFLLYQQPVLPVVR

a. Sequence identified using the one letter amino acid code where Σ = Ser(*P*)

The peptide κ -casein (106-169) is present in cheese whey or rennet whey in several different forms. The peptide has two major genetic variants (A and B) and is post-translationally modified by glycosylation and phosphorylation. The glycosylated forms, known as the

5 Kappa-caseino-glycopeptide or glycomacropeptide have been described by Neeser [US patent Nos. 4,992,420 and 4,994,441] as anti-plaque and anti-caries agents by virtue of the oligosaccharide chains linked to threonine residues of the peptide. Neeser claims that the oligosaccharide chains of the glycopeptide, by specifically binding to plaque-forming oral bacteria, block

10 the adherence of these bacteria onto salivary-coated tooth enamel. The glycosylated forms of κ -casein (106-169) can be separated from the non-glycosylated forms by chromatography (eg. anion exchange and reversed-phase HPLC) or by selective precipitation or ultrafiltration. Only the non-glycosylated forms of κ -casein (117-169) or κ -casein (106-169)

15 showed antimicrobial activity. As glycosylation destroys antimicrobial activity it is desirable to separate the glyco- and aglyco-forms of κ -casein (117-169) or κ -casein (106-169) which can be achieved using chromatography, selective precipitation or ultrafiltration. Phosphorylation of Ser¹⁴⁹ and to a lesser extent Ser¹²⁷ are important for antimicrobial activity

20 and the phosphorylated forms of the two major genetic variants (A and B) appear to possess equal activity [Table 1]. The Neeser patents do not disclose the antimicrobial activity of κ -casein(106-169) nor the use of the non-glycosylated forms of the peptide for the suppression of bacterial pathogens.

25 In a particularly preferred embodiment of the invention, the antimicrobial peptide is incorporated into dentifrices such as toothpaste, mouth washes or formulations for the mouth to aid in the prevention and/or treatment of dental caries and periodontal diseases. The peptide may comprise 0.01-50% by weight of the composition, preferably 0.1-10%. For

30 oral compositions it is preferred that the amount of the peptide administered is 0.01 -50% by weight, preferably 0.1-10% by weight of the composition. The oral composition of this invention which contains the above-mentioned peptides may be prepared and used in various forms applicable to the mouth such as dentifrice including toothpastes, toothpowders and liquid dentifrices,

35 mouthwashes, troches, chewing gums, dental pastes, gingival massage creams, gargle tablets, lozenges, dairy products and other foodstuffs. The

oral composition according to this invention may further include additional well known ingredients depending on the type and form of a particular oral composition.

In certain highly preferred forms of the invention the oral
5 composition may be substantially liquid in character, such as a mouthwash or rinse. In such a preparation the vehicle is typically a water-alcohol mixture desirably including a humectant as described below. Generally, the weight ratio of water to alcohol is in the range of from about 1:1 to about 20:1. The total amount of water-alcohol mixture in this type of preparation is
10 typically in the range of from about 70 to about 99.9% by weight of the preparation. The alcohol is typically ethanol or isopropanol. Ethanol is preferred.

The pH of such liquid and other preparations of the invention is generally in the range of from about 4.5 to about 9 and typically from about
15 5.5 to 8. The pH is preferably in the range of from about 6 to about 8.0, preferably 7.4. The pH can be controlled with acid (e.g. citric acid or benzoic acid) or base (e.g. sodium hydroxide) or buffered (as with sodium citrate, benzoate, carbonate, or bicarbonate, disodium hydrogen phosphate, sodium dihydrogen phosphate, etc).

20 Other desirable forms of this invention, the oral composition may be substantially solid or pasty in character, such as toothpowder, a dental tablet or a dentifrice, that is a toothpaste (dental cream) or gel dentifrice. The vehicle of such solid or pasty oral preparations generally contains dentally acceptable polishing material. Examples of polishing materials are
25 water-insoluble sodium metaphosphate, potassium metaphosphate, tricalcium phosphate, dihydrated calcium phosphate, anhydrous dicalcium phosphate, calcium pyrophosphate, magnesium orthophosphate, trimagnesium phosphate, calcium carbonate, hydrated alumina, calcined alumina, aluminium silicate, zirconium silicate, silica, bentonite, and
30 mixtures thereof. Other suitable polishing material include the particulate thermosetting resins such as melamine-, phenolic, and urea-formaldehydes, and cross-linked polyepoxides and polyesters. Preferred polishing materials include crystalline silica having particle sized of up to about 5 microns, a mean particle size of up to about 1.1 microns, and a surface area of up to
35 about 50,000 cm²/gm., silica gel or colloidal silica, and complex amorphous alkali metal aluminosilicate.

When visually clear gels are employed, a polishing agent of colloidal silica, such as those sold under the trademark SYLOID as Syloid 72 and Syloid 74 or under the trademark SANTOCEL as Santocel 100, alkali metal alumino-silicate complexes are particularly useful since they have refractive indices close to the refractive indices of gelling agent-liquid (including water and/or humectant) systems commonly used in dentifrices.

Many of the so-called "water insoluble" polishing materials are anionic in character and also include small amounts of soluble material. Thus, insoluble sodium metaphosphate may be formed in any suitable manner as illustrated by Thorpe's Dictionary of Applied Chemistry, Volume 9, 4th Edition, pp. 510-511. The forms of insoluble sodium metaphosphate known as Madrell's salt and Kurrol's salt are further examples of suitable materials. These metaphosphate salts exhibit only a minute solubility in water, and therefore are commonly referred to as insoluble metaphosphates (IMP). There is present therein a minor amount of soluble phosphate material as impurities, usually a few percent such as up to 4% by weight. The amount of soluble phosphate material, which is believed to include a soluble sodium trimetaphosphate in the case of insoluble metaphosphate, may be reduced or eliminated by washing with water if desired. The insoluble alkali metal metaphosphate is typically employed in powder form of a particle size such that no more than 1% of the material is larger than 37 microns.

The polishing material is generally present in the solid or pasty compositions in weight concentrations of about 10% to about 99%. Preferably, it is present in amounts from about 10% to about 75% in toothpaste, and from about 70% to about 99% in toothpowder. In toothpastes, when the polishing material is silicious in nature, it is generally present in amount of about 10-30% by weight. Other polishing materials are typically present in amount of about 30-75% by weight.

In a toothpaste, the liquid vehicle may comprise water and humectant typically in an amount ranging from about 10% to about 80% by weight of the preparation. Glycerine, propylene glycol, sorbitol and polypropylene glycol exemplify suitable humectants/carriers. Also advantageous are liquid mixtures of water, glycerine and sorbitol. In clear gels where the refractive index is an important consideration, about

2.5 - 30% w/w of water, 0 to about 70% w/w of glycerine and about 20-80% w/w of sorbitol are preferably employed.

Toothpaste, creams and gels typically contain a natural or synthetic thickener or gelling agent in proportions of about 0.1 to about 10, preferably 5 about 0.5 to about 5% w/w. A suitable thickener is synthetic hectorite, a synthetic colloidal magnesium alkali metal silicate complex clay available for example as Laponite (e.g. CP, SP 2002, D) marketed by Laporte Industries Limited. Laponite D is, approximately by weight 58.00% SiO₂, 25.40% MgO, 3.05% Na₂O, 0.98% Li₂O, and some water and trace metals. Its true specific 10 gravity is 2.53 and it has an apparent bulk density of 1.0 g/ml at 8% moisture.

Other suitable thickeners include Irish moss, iota carrageenan, gum tragacanth, starch, polyvinylpyrrolidone, hydroxyethylpropylcellulose, hydroxybutyl methyl cellulose, hydroxypropyl methyl cellulose, hydroxyethyl cellulose (e.g. available as Natrosol), sodium carboxymethyl 15 cellulose, and colloidal silica such as finely ground Syloid (e.g. 244). Solubilizing agents may also be included such as humectant polyols such propylene glycol, dipropylene glycol and hexylene glycol, cellosolves such as methyl cellosolve and ethyl cellosolve, vegetable oils and waxes containing at least about 12 carbons in a straight chain such as olive oil, castor oil and 20 petrolatum and esters such as amyl acetate, ethyl acetate and benzyl benzoate.

It will be understood that, as is conventional, the oral preparations are to be sold or otherwise distributed in suitable labelled packages. Thus, a jar of mouthrinse will have a label describing it, in substance, as a 25 mouthrinse or mouthwash and having directions for its use; and a toothpaste, cream or gel will usually be in a collapsible tube, typically aluminium, lined lead or plastic, or other squeeze, pump or pressurized dispenser for metering out the contents, having a label describing it, in substance, as a toothpaste, gel or dental cream.

Organic surface-active agents are used in the compositions of the present invention to achieve increased prophylactic action, assist in achieving thorough and complete dispersion of the active agent throughout the oral cavity, and render the instant compositions more cosmetically acceptable. The organic surface-active material is preferably anionic, 30 nonionic or ampholytic in nature which does not denature the antimicrobial peptide of the invention, and it is preferred to employ as the surface-active 35

agent a detergents material which imparts to the composition detergents and foaming properties while not denaturing the peptide. Suitable examples of anionic surfactants are water-soluble salts of higher fatty acid monoglyceride monosulfates, such as the sodium salt of the monosulfated monoglyceride of 5 hydrogenated coconut oil fatty acids, higher alkyl sulfates such as sodium lauryl sulfate, alkyl aryl sulfonates such as sodium dodecyl benzene sulfonate, higher alkylsulfo-acetates, higher fatty acid esters of 1,2-dihydroxy propane sulfonate, and the substantially saturated higher aliphatic acyl amides of lower aliphatic amino carboxylic acid compounds, such as those 10 having 12 to 16 carbons in the fatty acid, alkyl or acyl radicals, and the like. Examples of the last mentioned amides are N-lauroyl sarcosine, and the sodium, potassium, and ethanolamine salts of N-lauroyl, N-myristoyl, or N-palmitoyl sarcosine which should be substantially free from soap or similar higher fatty acid material. The use of these sarconite compounds in 15 the oral compositions of the present invention is particularly advantageous since these materials exhibit a prolonged marked effect in the inhibition of acid formation in the oral cavity due to carbohydrates breakdown in addition to exerting some reduction in the solubility of tooth enamel in acid solutions. Examples of water-soluble nonionic surfactants suitable for use with peptides 20 are condensation products of ethylene oxide with various reactive hydrogen-containing compounds reactive therewith having long hydrophobic chains (e.g. aliphatic chains of about 12 to 20 carbon atoms), which condensation products ("ethoxamers") contain hydrophilic polyoxyethylene moieties, such as condensation products of poly (ethylene oxide) with fatty 25 acids, fatty alcohols, fatty amides, polyhydric alcohols (e.g. sorbitan monostearate) and polypropyleneoxide (e.g. Pluronic materials).

Surface active agent is typically present in amount of about 0.1-5% by weight. It is noteworthy, that the surface active agent may assist in the dissolving of the peptide of the invention and thereby diminish the amount 30 of solubilizing humectant needed.

Various other materials may be incorporated in the oral preparations of this invention such as whitening agents, preservatives, silicones, chlorophyll compounds and/or ammoniated material such as urea, diammonium phosphate, and mixtures thereof. These adjuvants, where 35 present, are incorporated in the preparations in amounts which do not substantially adversely affect the properties and characteristics desired.

Any suitable flavouring or sweetening material may also be employed. Examples of suitable flavouring constituents are flavouring oils, e.g. oil of spearmint, peppermint, wintergreen, sassafras, clove, sage, eucalyptus, marjoram, cinnamon, lemon, and orange, and methyl salicylate.

5 Suitable sweetening agents include sucrose, lactose, maltose, sorbitol, xylitol, sodium cyclamate, perillartine, AMP (aspartyl phenyl alanine, methyl ester), saccharine, and the like. Suitably, flavour and sweetening agents may each or together comprise from about 0.1% to 5% more of the preparation.

In the preferred practice of this invention an oral composition
10 according to this invention such as mouthwash or dentifrice containing the composition of the present invention is preferably applied regularly to the gums and teeth, such as every day or every second or third day or preferably from 1 to 3 times daily, at a pH of about 4.5 to about 9, generally about 5.5 to about 8, preferably about 6 to 8, for at least 2 weeks up to 8 weeks or more up
15 to a lifetime.

The compositions of this invention can be incorporated in lozenges, or in chewing gum or other products, e.g. by stirring into a warm gum base or coating the outer surface of a gum base, illustrative of which may be mentioned jelutong, rubber latex, vinylite resins, etc., desirably with
20 conventional plasticisers or softeners, sugar or other sweeteners or such as glucose, sorbitol and the like.

In another embodiment, the peptide of the invention is formulated in foods to act as a preservative preferably comprising 0.01-10% w/w, more preferably 0.1-5% w/w, most preferably 1-5% and particularly 2% w/w.

25 The present invention provides compositions including pharmaceutical compositions comprising the antimicrobial peptide as described together with a pharmaceutically-acceptable carrier. Such compositions may be selected from the group consisting of dental, intra-oral compositions, therapeutic anti-infective compositions for topical and
30 systemic application. Dental compositions or therapeutic compositions may be in the form of a gel, liquid, solid, powder, cream or lozenge. Therapeutic compositions may also be in the form of tablets or capsules.

The present invention also provides a method of treating or preventing dental caries or periodontal disease comprising the step of
35 administering a peptide or composition of the invention to the teeth or gums

of a subject in need of such treatments. Topical administration of the peptide is preferred.

The invention also provides a method of producing the antimicrobial peptide from casein or whey. κ -casein (106-169) can be obtained from cheese or rennet whey by ultrafiltration or acid precipitation. Ultrafiltration of whey through a 10,000 - 30,000 nominal molecular weight cut off (NMCO) membrane filter at neutral or preferably acidic pH (3-5) retains the majority of whey proteins producing a permeate rich in casein peptides, lactose and minerals. Ultrafiltration and concentration of the permeate using a 1000 NMCO membrane filter produces a fraction rich in κ -casein (106-169). This fraction is then incubated with trypsin and the resulting hydrosylate subjected to reversed-phase HPLC producing a relatively pure κ -casein (117-169) peptide. Alternatively the peptides κ -casein (117-169) and β (184-202) can be obtained from a tryptic digest of casein using reversed-phase HPLC. Peptide κ -casein (138-158) can be obtained by a partial endo-Glu-C digest of κ -casein (106-169) followed by purification using reversed-phase HPLC.

It will be clearly understood that, although this specification refers specifically to applications in humans, the invention is also useful for veterinary purposes. Thus in all aspects the invention is useful for domestic animals such as cattle, sheep, horses and poultry; for companion animals such as cats and dogs; and for zoo animals.

In order that the nature of the present invention may be more clearly understood preferred forms thereof will now be described with reference to the following non-limiting examples.

FIGURE LEGENDS

Figure 1. Reversed-phase HPLC of a tryptic digest of a Whey Protein Concentrate (WPC). The WPC tryptic digest (8 mg) was applied to a Brownlee RP-300 C₈ column. The sample was eluted using a stepwise linear gradient of 0 - 20% B in 2 min followed by 20 - 45% B in 40 min at a flow rate of 1 ml/min. Eluant A was 0.1% (v/v) TFA in water and eluant B was 80% (v/v) acetonitrile in 0.1% (v/v) TFA in water.

Figure 2. Anion exchange chromatography of peak 9 from RP-HPLC of the WPC tryptic digest. Peak 9 was applied to a Mono Q column attached to a SMART™ system and eluted using 0 - 75% elutant B in 40 min at a flow rate of 100 µl/min. Elutant A was 20 mM Tris-HCl pH 8.0 , 10 mM KCl and
5 elutant B was 20 mM Tris-HCl pH 8.0, 500 mM KCl.

Figure 3. Determination of the MIC of κ -casein A Ser(*P*)¹⁴⁹ (f117-169) for *Streptococcus mutans* Ingbratt. The MIC was 2.4 μ M.

10 Figure 4. Analytical reversed-phase HPLC elution profile of UF-whey. A sample of UF-whey was dissolved in solvent A and applied to an analytical column (C18) and then eluted using a linear gradient from 0-35% Solvent B in 5 min followed by 35-80% Solvent B in 40 min at a flow rate of 1.0 ml/min. Solvent A consisted of 0.1% TFA in water and Solvent B contained 90% acetonitrile (v/v/0.1% TFA in water). Peaks were detected at 15 215 nm, collected manually at 215 nm and lyophilised.

Figure 5. Purification of peak 4 (from RP-HPLC) using gel filtration. Peak 4 was applied to a gel filtration column connected to an ABI system.
20 Material was eluted using 30% acetonitrile (v/v)/0.1% TFA at a flow rate of 1 ml/min and monitored at 215 nm.

Figure 6. Purification of peptides generated by the hydrolysis of TCA-soluble UF-whey by endopeptidase Glu-C. A sample was dissolved in
25 Solvent A (0.1% TFA v/v in water) and applied to an analytical column (C18). Peaks were eluted using a gradient of 0-20% Solvent B (90% acetonitrile v/v/0.1% TFA in water) in 4 min followed by 20%-40% Solvent B in 40 min. Peaks were monitored at 215 nm.

30 Specific examples of formulations containing the antimicrobial peptide of the invention are provided below.

EXAMPLE 1

Preparation of antimicrobial peptides from a tryptic digest of whey protein concentrate

5 Whey protein concentrate (50 mg/ml) in water (pH 8.0) was hydrolysed using Novo trypsin (1 mg/ml) at 50°C for 2 h with the pH maintained at 8.00 ± 0.01 by the addition of 1N NaOH. Hydrolysis was terminated by the addition of 1M HCl to pH 4.6. The hydrolysate was centrifuged (11,600 g for 10 min) and then filtered through a 0.2 µm PVDF
10 filter before being applied to a 7 µm C₈ (Brownlee) reversed-phase column (4.6 x 220 mm). The sample was eluted using an Applied Biosystems 140 A Solvent Delivery System to generate a stepwise linear gradient from 0-20% B in 2 min followed by 20-45% B in 40 min at a flow rate of 1 ml/min. Eluant A was 0.1% (v/v) TFA in water and eluant B was 80% (v/v) acetonitrile,
15 0.1% (v/v) TFA in water. The eluant was monitored using an Applied Biosystems 1000S Diode Array detector at a primary wavelength of 215 nm. The chromatogram obtained is shown in Fig. 1. Peaks were collected and assayed for antimicrobial activity. Antimicrobial assays were carried out in liquid growth medium using sterile 96 well plates, each well having a
20 capacity of 300 µL. The growth medium consisted of Todd Hewitt broth (36.4 g/L), Yeast Extract (5.0 g/L) with 100 mmol/L potassium phosphate buffer. Routinely the pH of the growth medium was adjusted to 6.3. An inoculum of approximately 1.5 X 10² cells (*Streptococcus sanguis*,
Streptococcus mutans, *Porphyromonas gingivalis*) that had been harvested
25 during the exponential phase of growth, was added to each well. The ionophore gramicidin (40 µmol/L final concentration) was added to a series of wells as a negative control. Positive controls contained only the inoculum and the growth medium. Growth was determined over a 30 hour period after inoculation by measuring the optical density of the cell suspensions at a
30 wavelength of 650 nm (OD₆₅₀), using a microplate reader (Biorad, model 450). Growth was determined by subtracting the initial reading, taken immediately after inoculation from the final reading (maximum culture OD).

Antimicrobial assays were also carried out on agar plates containing suitable growth media that had been inoculated with a lawn of the test
35 bacterial species. Filter paper discs (6 mm diameter), to which was added 50 µL of the peptide solution, were placed on the surface of the agar plate.

The diameter of the zone of growth inhibition around each disc was determined after three days of incubation and compared to a control that only had buffer added. Growth conditions depended on the bacterial species being tested, however they were routinely cultured in an anaerobic work station at 37 °C. Only peak 9 of Fig. 1 exhibited antimicrobial activity.

Analysis of this peak using amino acid sequence analysis (Hewlett Packard automated protein sequencer) and mass analysis (Perseptive Voyager MALDI-TOF mass spectrometer) revealed that the peak was heterogenous and so the sample was subjected to anion exchange chromatography on a Mono Q PC 1.6/5 (10 µm) column attached to a SMART™ (Pharmacia) system. The sample was eluted using a linear gradient from 0-75% B in 40 min at a flow rate of 100 µl/min. Eluant A was 20 mM Tris-HCl pH 8.0, 10 mM KCl. Eluant B was 20 mM Tris-HCl pH 8.0, 500 mM KCl. The eluant was monitored at 215 and 280 nm using the µ Peak monitor. The anion exchange chromatogram for peak 9 from RP-HPLC is shown in Fig. 2. Peaks were collected and assayed for antimicrobial activity and only peaks 9, 10 and 11 exhibited activity. N-terminal sequence and mass analyses revealed that fraction 9 contained Ser(P)¹⁴⁹ κ-casein A (113-169), fraction 10 contained Ser(P)¹⁴⁹ κ-casein A (124-169) and fraction 11 contained Ser(P)¹⁴⁹ κ-casein A (117-169). Mass analysis revealed that none of the peptides were glycosylated. The minimum inhibitory concentration (MIC) of pure Ser(P)¹⁴⁹ κ-casein A (117-169) was then determined for the bacterium *Streptococcus mutans* and is shown in Fig. 3. The MIC obtained was 2.4 µM.

25 **EXAMPLE 2**

A. *Preparation of antimicrobial peptides from cheese whey*

Cheese whey was ultrafiltered (UF) though a 20,000 molecular weight cut off membrane. The filtrate was collected and proteins were precipitated by addition of trichloroacetic acid (TCA) to a final concentration of 11% w/v. Precipitated proteins were removed by centrifugation (10,000g, 5 min) and the neutralised supernatant was lyophilised. The dried TCA-soluble UF whey was dissolved in 0.1% TFA in water and subjected to RP-HPLC. The sample was applied to a Brownlee aquapore analytical (C18) reversed-phase column (220 x 4.6 mm) or a Brownlee (C18) preparative column (25 cm x 10 mm). Solvent B consisted of 90% acetonitrile containing 0.1 % v/v TFA and

solvent A consisted of 0.1% TFA in water. The eluant was monitored using an Applied Biosystems Incorporated (ABI; Melbourne, Vic., Australia) 1000S diode array detector at a wavelength of 215 nm.

The sample was applied to the Brownlee analytical column and
5 eluted using a gradient from 0-35% solvent B in 2 min, 35% solvent B in 2 min followed by 35-80% solvent B in 40 min at a flow rate of 1.0 ml/min. Fractions collected were assayed for antibacterial activity. Fractions were tested with the Gram-positive bacteria *Streptococcus mutans* Ingbratt, *Streptococcus sanguinis* (formerly *S. sanguis*), *Streptococcus sobrinus* 6715
10 WT15, *Staphylococcus aureus* ATCC 25923 and the Gram-negative bacteria, *Escherichia coli* NCTC 10418, *Salmonella typhimurium* ATCC 13311, and *Pseudomonas aeruginosa* ATCC 25619. The bacteria were stored in 30% glycerol broths at -20°C.

The antibacterial assay was conducted in sterile 96 well plates
15 (Becton Dickinson, Melbourne, Australia). The growth media for the Gram-positive bacteria consisted of Todd Hewitt broth (TH; 36.4 g/l), Yeast extract (YE; 5 g/l) and 100 mM potassium phosphate, pH 6.28 (TYPB). The media for Gram-negative bacteria consisted of Nutrient broth at pH 6.28 and for *P. gingivalis*, Brain Heart Infusion media (with 1µg/ml haeme and 0.5g/l
20 cysteine) at pH 7.0. An inoculum was prepared by diluting exponentially growing cells in growth media, such that the inoculum contained approximately 2.7×10^4 viable cells/ml. To each well was added 250 µl media containing the peptide in varying concentrations and 50 µl of bacterial inoculum. Control assays contained all components except peptide. The
25 negative control wells each contained 250 µl media, 50 µl inoculum and 5 µl of gramicidin D (2.5 mM). Growth of the bacterium was determined as the difference between the final and initial Optical Density (OD) 650 nm readings using a microplate reader (BIORAD, model 450, NSW, Australia). The final OD represented the maximum culture OD and was recorded
30 normally 20-30 h after inoculation, during which time the cells were incubated at 37°C in aerobic conditions except for *P. gingivalis* which was incubated in anaerobic conditions at the same temperature. The minimal inhibitory concentration (MIC) was determined as the lowest concentration of peptide required to inhibit the growth of the bacterium. The peptide
35 concentration varied between 0.05 µM-500 µM

The antimicrobial activity of the neutralised starting material (TCA-soluble UF whey) is shown in Table 2.

Table 2. Growth inhibition of Gram-positive and Gram-negative bacteria by TCA-soluble UF-whey. Microbial growth was determined by optical density at a wavelength of 650 nm after 30 h incubation at 37°C.

Species	Growth Inhibition by TCA-soluble UF-whey %	
	3.7 mg/ml	1.9 mg/ml
Gram-positive bacteria		
<i>S. mutans</i>	89 ± 6 ^a	42 ± 11
<i>S. aureus</i>	47 ± 18	18 ± 18
<i>S. sanguinis</i>	NI ^b	NI
Gram-negative bacteria		
<i>E. coli</i>	14 ± 8	12 ± 15
<i>S. typhimurium</i>	8 ± 7	NI
<i>P. aeruginosa</i>	9 ± 6	NI

a-% mean inhibition of growth ± standard deviation (n=3-6)

b- no inhibition

Fig. 4 shows the RP-HPLC of the TCA-soluble UF whey. Five peaks were collected and analysed for antibacterial activity. Peak 4 exhibited the highest specific antimicrobial activity as shown in Table 3. Peak 4 (RP4) was further subjected to gel filtration chromatography using a gel filtration column (Supelco 30 x 7.8 cm) and eluted using 30% acetonitrile v/v 0.1% TFA in water at a flow rate of 1 ml/min.

Table 3: Growth inhibition of streptococcal species by RP-HPLC peaks of UF-whey. The peaks generated were tested in the antibacterial assay. Microbial growth was determined by optical density at a wavelength of 650 nm after 30 h incubation at 37°C.

5

Sample	Amount [†] (mg)	Assay concentration [∞] (mg/ml)	% Growth Inhibition		
RP1 + RP2	1.7	1.4	<i>S. mutans</i> 23 ± 16^a	<i>S. sobrinus</i> — ^b	<i>S. sanguinis</i> NI ^c
RP3	1.0	0.90	17 ± 16	23 ± 20	17 ± 7
RP4	0.64	0.53	91 ± 3	81 ± 5	26 ± 7
RP5	0.60	0.50	79 ± 7	79 ± 14	23 ± 5

a - % mean inhibition of growth ± standard deviation (n=3-6)

b - not determined

c - no inhibition

† - Amount of each peak estimated by 215nm absorbance

10 ∞ - Concentration of peak in antibacterial assay

Fig. 5 shows the gel filtration chromatography of peak 4 (RP4) from RP-HPLC of the TCA-soluble UF whey. Four peaks from the chromatography were collected and assayed for antimicrobial activity against *S. mutans* as shown
15 in Table 4.

Table 4. The inhibition of growth of *S. mutans* by gel filtration peaks of peak 4 from RP-HPLC of TCA-soluble whey.

Peak	Amount [†] (mg)	Assay Concentration [∞] (mg/ml)	%Growth inhibition
RP4GF1	3.12	2.6	46 ± 9 ^a
RP4GF2	- ^b	-	NI ^c
RP4GF3	19.2	16	26 ± 12
RP4GF4	2.88	2.4	41 ± 11

a - % mean inhibition of growth ± standard deviation (n=3-6)

5 b - not determined

c - no inhibition

† - Amount of each peak estimated by 215nm absorbance

∞ - Concentration of peak in antibacterial assay

10 The four peaks were also analysed by amino acid sequence analysis and by mass spectrometry.

Mass spectrometric analysis (MS) of peptides was performed using a Perspective Biosystems (Framingham, MA, USA) Voyager linear matrix 15 assisted laser desorption/ionisation Time of Flight (MALDI-TOF) mass spectrometer equipped with delayed extraction. Samples were mixed (1:1 v/v) on the sample analysis plate with a 5 mg/ml solution of 2-5, dihydroxybenzoic acid in 50% aqueous acetonitrile, containing 0.25% v/v TFA in water. All spectra were obtained in linear, positive mode with an 20 accelerating voltage of 20 kV, grid voltage of 92% and pulse delay time of 125 ns. Calibration was performed using bovine insulin (MW 5733.54 Da). For sequence analysis peptides were applied to a preconditioned Hewlett-Packard (HP; Blackburn, Vic, Aust.) sequencing column in 1 ml of sample loading solution (2% v/v TFA in water) and then analysed using a HP 25 G1005A Protein sequencer.

Table 5. Comparison of the peaks from gel filtration chromatography of peak 4 (RP4) of TCA-soluble UF whey as determined by sequence and mass spectrometric analysis.

Peak	Measured Mass (Da)	Calculated Mass (Da)	Assignment [†]
RP4GF1	6756	6755	Ser(P) ¹⁴⁹ κ-casein-B-(106-169)
	6788	6787	Ser(P) ¹⁴⁹ κ-casein-A-(106-169)
	6736	6835	Ser(P) ¹²⁷ , Ser(P) ¹⁴⁹ κ-casein-B-(106-169)
	6869	6867	Ser(P) ¹²⁷ , Ser(P) ¹⁴⁹ κ-casein-A-(106-169)
RP4GF2	-	-	β-lactoglobulin, minor traces of α-lactalbumin and κ-casein (106-169)
RP4GF3	-	-	α-lactalbumin
RP4GF4	6758	6755	Ser(P) ¹⁴⁹ κ-casein-B-(106-169)
	6788	6787	Ser(P) ¹⁴⁹ κ-casein-A-(106-169)
	6738	6835	Ser(P) ¹²⁷ , Ser(P) ¹⁴⁹ κ-casein-B-(106-169)
	6869	6867	Ser(P) ¹²⁷ , Ser(P) ¹⁴⁹ κ-casein-A-(106-169)

5 † - Assigned by N-terminal amino acid sequencing

The two gel filtration peaks with the same specific antimicrobial activity RP4 GF1 and RP4 GF4 (Table 4) contained the same peptides, presumably the higher molecular weight fraction RP4 GF1, represented an aggregated state of the phosphopeptides. The active peptides were identified as:

10 Ser(P)¹⁴⁹κ-casein-B-(106-169)
 Ser(P)¹⁴⁹κ-casein-A-(106-169)
 Ser(P)¹²⁷, Ser(P)¹⁴⁹κ-casein-B-(106-169)
 Ser(P)¹²⁷, Ser(P)¹⁴⁹κ-casein-A-(106-169)

15 The identification of antimicrobial activity with the phosphorylated, non-glycosylated form of κ-casein (106-169) is consistent with the identification of the tryptic casein peptide Ser(P)¹⁴⁹ κ-casein (117-169) as an antimicrobial peptide in Example 1.

B. Preparation of antimicrobial peptides from TCA-soluble UF whey treated with endopeptidase Glu-C

Endopeptidase Glu-C (Sigma Chemical Co, St. Louis, MO, USA) was added (5.0 µg/ml) to a solution of TCA-soluble UF-whey (1.0 mg/ml), in ammonium acetate (0.05 M, pH 4.0) and incubated at 37°C for 24 h. The reaction was stopped by lowering the pH to 3.0 by the addition of glacial acetic acid. Enzymatic digestion products were separated by RP-HPLC.

Fig. 6 shows the RP-HPLC of the endo Glu-C digest of TCA-soluble UF whey. Twelve peaks were collected and only peak 12 exhibited antimicrobial activity against *S. mutans* as shown in Table 6. Peak 12 contained three peptides as shown by sequence and mass spectrometric analyses (Table 7). These peaks were further purified by analytical RP-HPLC and only peptide Ser(*P*)¹⁴⁹ κ-casein A (138-158) exhibited antimicrobial activity with a 100 µM concentration giving close to 100% growth inhibition of *S. mutans*.

Table 6. Antimicrobial activity against *S. mutans* of lyophilised peaks 9-12 from RP-HPLC of an endo Glu-C hydrolysate of TCA-soluble UF-whey.

20

Peak	Amount [†] (mg)	Assay Concentration [∞] (mg/ml)	% Growth inhibition
9	0.64	0.53	NI ^a
10	0.30	0.25	NI
11	0.32	0.27	NI
12	0.40	0.34	84±9 ^b

a - no inhibition

b - % mean inhibition of growth ± standard deviation (n=3)

† - Amount of each peak estimated by 215nm absorbance

∞ - Concentration of peak in antibacterial assay

25

Table 7. Composition of peaks 9-12 from RP-HPLC of an endo Glu-C hydrolysate of TCA-soluble UF-whey.

Peak	Measured Molecular mass (Da) ^a	Calculated Molecular mass (Da)	Assignment
9	3056.5	3050.2	Ser (P) ¹⁴⁹ κ-casein-B-(141-151)
	4080.9	4076.2	κ-casein-A-1 GalNAc, 1 Gal-(106-140)
	4373.7	4367.2	κ-casein-A-1 GalNAc, 1Gal, 1NeuAc-(106-140) + methionine sulfoxide
	4750.9	4748.0	κ-casein-A-2 GalNAc, 2Gal, 1NeuAc-(106-140)
	5040.8	5039.0	κ-casein-A-2 GalNAc, 2Gal, 2NeuAc-(106-140) + methionine sulfoxide
10	2438.2	2432.4	κ-casein-A-1 GalNAc-(119-140)
	2481.9	2474.0	Ser (P) ¹⁴⁹ κ-casein-A-1 GalNAc, 1 NeuAc-(141-158)
	3423.8	3423.0	κ-casein-B-(106-137)
	4092.5	4092.2	κ-casein-A-1 GalNAc, 1 Gal-(106-140) + methionine sulfoxide
	4383.7	4383.2	κ-casein-A-1 GalNAc, 1 Gal, 1 NeuAc-(106-140) + methionine sulfoxide
11	1890.1	1884.1	κ-casein-A-(152-169) and κ-casein-B-(152-169)
	2938.4	2931.2	κ-casein-A-(119-147)
	3427.4	3423.8	κ-casein-B-(106-137)
	4094.2	4088.0	κ-casein-B-1 GalNAc, 1 Gal-(106-140)
	4385.3	4379.0	κ-casein-B-1 GalNAc, 1 Gal, 1 NeuAc-(106-140)
12	2285.6	2279.3	Ser (P) ¹⁴⁹ κ-casein-A-(138-158)
	2356.8	2348.4	Ser (P) ¹⁴⁹ κ-casein-B-(148-169)
	2398.3	2392.5	Ser (P) ¹⁴⁹ κ-casein-A-(148-169)

a - molecular mass determined by MS

These results showed that only a 20 residue fragment of Ser(*P*)¹⁴⁹ κ-casein A (106-169), Ser(*P*)¹⁴⁹ κ-casein A (138-158) displayed antimicrobial activity albeit less potent (100 μM MIC) compared with the longer peptide (2.5 μM MIC). The twenty residue fragment of the two major 5 genetic variants A and B are shown:

Ser(*P*)¹⁴⁹ κ-casein A (138-158) AVESTVATLEDΣPEVIESPP

Ser(*P*)¹⁴⁹ κ-casein B (138-158) AVESTVATLEAΣPEVIESPP

The twenty residue fragment is amphipathic and has the potential to form an amphipathic helix and therefore a channel in the bacterial 10 membrane. A molecular model of κ-casein (130-158) as a hexamer forming a polar channel with a non-polar exterior that could allow the passage of cations (Na⁺, K⁺, H⁺ etc.) through a bacterial cell membrane thereby dissipating transmembrane electrochemical gradients was constructed. It 15 was interesting to note that the molecular model of the glycosylated form of κ-casein (130-158), which has no antimicrobial activity, has the channel blocked by sugar residues perhaps thereby possibly explaining the lack of activity with the glycosylated peptides.

C. *Synthesis of Ser(*P*)¹⁴⁹ κ-casein (138- 160)*

To confirm antimicrobial activity of Ser(*P*)¹⁴⁹ κ-casein (138-158) 20 related peptides were synthesised with and without the phosphorylation and assayed for antimicrobial activity.

A peptide corresponding to Ser(*P*)¹⁴⁹ κ-casein A (138-160), containing 25 a phosphoryl group on Ser 149, and κ-casein A (130-158) were synthesised manually by standard solid-phase peptide synthesis protocols for Fmoc chemistry. The peptides were assembled as the carboxyl form using Pac-Peg-PS resin (PerSeptive Biosystems). Subsequent additions of the remaining Fmoc amino acids including Fmoc-Ser(PO(OBzl)OH)-OH were 30 accomplished with HBTU/HOBt activation using 4 equiv of Fmoc-amino acid and 6 equiv of DIPEA. The Fmoc group was removed with a continuous flow of 2% v/v DBU in DMF containing 2% v/v piperidine for 5 min. Cleavage of the peptide from the resin support was performed using TFA:TIPS:water (95:2.5:2.5) cleavage cocktail for 2.5 h under N₂, in darkness. After cleavage 35 the resin was removed by filtration and the filtrate concentrated under a stream of nitrogen. After the peptide products were precipitated in cold

ether, they were centrifuged and washed three times. The peptide precipitate was then dissolved in water containing 0.1% v/v TFA and insoluble residue removed by centrifugation.

Purification of synthesised peptides was performed using a Brownlee C18 preparative column. Chromatograms were developed at a flow rate of 4.0 ml/min and peptides were eluted using a gradient of 0-100 % solvent B in 43 min. Peptide fractions collected from the column were applied to the Brownlee C18 analytical column and eluted using a gradient of 0-100% solvent B in 40 min.

All collected peptide fractions were lyophilised and subjected to analysis by MS.

Table 8 shows the antimicrobial activity of the two synthetic peptides. These results show that the phosphorylation of Ser¹⁴⁹ is essential for full antimicrobial activity. The phosphoseryl residue Ser(P)¹⁴⁹ may be necessary for the formation of an ion channel in the bacterial membrane or maybe necessary for solubility. Further, the higher MIC (100-150 µM) for the Ser(P)¹⁴⁹ κ-casein A (138-160) compared with the larger peptide Ser(P)¹⁴⁹ κ-casein A (117-169) (2.5 µM MIC) suggests that the flanking residues of Ser(P)¹⁴⁹ κ-casein (138-158) may be necessary for solubility and/or interaction with the bacterial cell and formation of the ion channel.

Table 8. Inhibition of *S. mutans* growth by synthetic peptides κ-casein-A-(130-158) (non-phosphorylated) and Ser (P)¹⁴⁹ κ-casein-A-(138-160).

25

Peptide	MIC	% Growth inhibition					
		Concentration of synthetic peptides (mM)					
		100	75	50	25	10	
κ-casein-A-(130-158)	1.2 mM	17 ± 13 ^a	- ^b	14 ± 13	11 ± 7	NI ^c	
Ser (P) ¹⁴⁹ κ-casein-A-(138-160)	150 µM	-	69 ± 6	52 ± 5	17 ± 9	6 ± 10	

a - % mean inhibition of growth ± standard deviation (n=3-6)

b - not determined

c - no inhibition

EXAMPLE 3*A. Trypsin hydrolysis*

Sodium caseinate was dissolved in 150 mM NH₄HCO₃ pH 8.0 at 10% (w/v) and hydrolysed using Novo trypsin (2 g/L) at 50 °C for 2 h. Hydrolysis was terminated by the addition of 1N HCl to pH 4.6 and the undigested protein removed by centrifugation. A sample of the hydrolysate was applied to a 7 µm Applied Biosystems C₈ column (4.6 x 220 mm) and eluted as described in Example 1. Peaks were collected and assayed for antimicrobial activity against *Streptococcus sanguinis*. Two peptides showed activity, Ser(P)¹⁴⁹ κ-casein (117-169) and β-casein (184-702).

B. Rennet hydrolysis

Casein HCl (5 g) was dissolved in 100 ml of 100 mM ammonium bicarbonate pH 8.0. Once the casein had dissolved the pH was lowered to 6.3 with 1 M HCl and 1 mg of rennet (chymosin, Sigma) was added and the mixture incubated for 1 h at 37°C. TCA (11% w/v) was added to the solution or the pH was lowered to 4.5 by the addition of 1 M HCl and the precipitated proteins were removed by centrifugation. The supernatant was collected, neutralised and lyophilised. The dried sample was dissolved in solvent A (0.1% TFA in water) and applied to a Brownlee C18 preparative RP-HPLC column. The column was eluted using a gradient of 15% solvent B for 5 min 15-60% solvent B in 225 min followed by 60-100% solvent B in 1 min at a flow rate of 4.0 ml/min. The eluant was monitored at 215 nm. Four peaks were obtained two of which had antimicrobial activity and corresponded to the non-glycosylated, phosphorylated κ-casein (106-169).

The active peptides were identified as:-

Ser(P)¹⁴⁹ κ-casein A (106-169).
30 Ser(P)¹²⁷, Ser(P)¹⁴⁹ κ-casein A (106-169)
and
Ser(P)¹⁴⁹ κ-casein B (106-169).
Ser(P)¹²⁷, Ser(P)¹⁴⁹ κ-casein B (106-169).

EXAMPLE 4 - PROPOSED TOOTHPASTE FORMULATIONS**Formulation 1**

Ingredient	% w/w
Dicalcium phosphate dihydrate	50.0
Glycerol	20.0
Sodium carboxymethyl cellulose	1.0
Sodium lauryl sulphate	1.5
Sodium lauroyl sarcosinate	0.5
Flavour	1.0
Sodium saccharin	0.1
Chlorhexidine gluconate	0.01
Dextranase	0.01
Ser(P) ¹⁴⁹ κ-casein(106-169)	1.0
Water	balance

Formulation 2

Ingredient	% w/w
Dicalcium phosphate dihydrate	50.0
Sorbitol	10.0
Glycerol	10.0
Sodium carboxymethyl cellulose	1.0
Sodium lauryl sulphate	1.5
Sodium lauroyl sarcosinate	0.5
Flavour	1.0
Sodium saccharin	0.1
Sodium monofluorophosphate	0.3
Chlorhexidine gluconate	0.01
Dextranase	0.01
Ser(P) ¹⁴⁹ κ-casein(106-169)	2.0
Water	balance

Formulation 3

Ingredient	% w/w
Dicalcium phosphate dihydrate	50.0
Sorbitol	10.0
Glycerol	10.0
Sodium carboxymethyl cellulose	1.0
Lauroyl diethanolamide	1.0
Sucrose monolaurate	2.0
Flavour	1.0
Sodium saccharin	0.1
Sodium monofluorophosphate	0.3
Chlorhexidine gluconate	0.01
Dextranase	0.01
Ser(<i>P</i>) ¹⁴⁹ κ-casein(106-169)	5.0
Water	balance

Formulation 4

Ingredient	% w/w
Sorbitol	10.0
Irish moss	1.0
Sodium Hydroxide (50%)	1.0
Gantrez	19.0
Water (deionised)	2.69
Sodium monofluorophosphate	0.76
Sodium saccharin	0.3
Pyrophosphate	2.0
Hydrated alumina	48.0
Flavour oil	0.95
Ser(<i>P</i>) ¹⁴⁹ κ-casein(106-169)	1.0
Water	balance

Formulation 5

Ingredient	% w/w
Sodium polyacrylate	50.0
Sorbitol	10.0
Glycerol	20.0
Sodium saccharin	0.1
Sodium monofluorophosphate	0.3
Chlorhexidine gluconate	0.01
Ethanol	3.0
Ser(<i>P</i>) ¹⁴⁹ κ-casein(106-169)	2.0
Linolic acid	0.05
Water	balance

EXAMPLE 5 - PROPOSED MOUTHWASH FORMULATIONS**Formulation 1**

Ingredient	% w/w
Ethanol	20.0
Flavour	1.0
Sodium saccharin	0.1
Sodium monofluorophosphate	0.3
Chlorhexidine gluconate	0.01
Lauroyl diethanolamide	0.3
Ser(<i>P</i>) ¹⁴⁹ κ-casein(106-169)	2.0
Water	balance

Formulation 2

Ingredient	% w/w
Gantrez S-97	2.5
Glycerine	10.0
Flavour oil	0.4
Sodium monofluorophosphate	0.05
Chlorhexidine gluconate	0.01
Lauroyl diethanolamide	0.2
Ser(<i>P</i>) ¹⁴⁹ κ-casein(106-169)	2.0
Water	balance

EXAMPLE 6 - PROPOSED LOZENGE FORMULATION

Ingredient	% w/w
Sugar	75-80
Corn syrup	1-20
Flavour oil	1-2
NaF	0.01-0.05
Ser(<i>P</i>) ¹⁴⁹ κ-casein(106-169)	3.0
Mg stearate	1-5
Water	balance

EXAMPLE 7 - PROPOSED GINGIVAL MASSAGE CREAM FORMULATION

Ingredient	% w/w
White petrolatum	8.0
Propylene glycol	4.0
Stearyl alcohol	8.0
Polyethylene Glycol 4000	25.0
Polyethylene Glycol 400	37.0
Sucrose monostearate	0.5
Chlorohexidine gluconate	0.1
Ser(<i>P</i>) ¹⁴⁹ κ-casein(106-169)	3.0
Water	balance

EXAMPLE 8 - PROPOSED CHEWING GUM FORMULATION

Ingredient	% w/w
Gum base	30.0
Calcium carbonate	2.0
Crystalline sorbitol	53.0
Glycerine	0.5
Flavour oil	0.1
Ser(<i>P</i>) ¹⁴⁹ κ-casein(106-169)	2.0
Water	balance

It will be appreciated by persons skilled in the art that numerous variations and/or modifications may be made to the invention as shown in the specific embodiments without departing from the spirit or scope of the
5 invention as broadly described. The present embodiments are, therefore, to be considered in all respects as illustrative and not restrictive.

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Thr Ala Val
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15 Ser Thr Ala Val
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20 SEQ ID NO: 13
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Glu Val Ile Glu Ser Pro Pro Glu Ile Asn Thr Val Gln Val Thr Ser
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20 25 30

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SEQ ID NO: 15
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 20 25 30

Ala Val Glu Ser Thr Val Ala Thr Leu Glu Asp Ser Pro Glu Val Ile
 35 40 45

15 Glu Ser Pro Pro Glu Ile Asn Thr Val Gln Val Thr Ser Thr Ala Val
 50 55 60

20 SEQ ID NO: 16
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<213> Bovine

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30 Thr Pro Thr Ile Glu Ala Val Glu Ser Thr Val Ala Thr Leu Glu Ala
 20 25 30

Ser Pro Glu Val Ile Glu Ser Pro Pro Glu Ile Asn Thr Val Gln Val
 35 40 45

35 Thr Ser Thr Ala Val
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40 SEQ ID NO: 17
<211> 53
<212> PRT
<213> Bovine

45 <400> 17
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 1 5 10 15

50 Thr Pro Thr Thr Glu Ala Val Glu Ser Thr Val Ala Thr Leu Glu Asp
 20 25 30

Ser Pro Glu Val Ile Glu Ser Pro Pro Glu Ile Asn Thr Val Gln Val
 35 40 45

55 Thr Ser Thr Ala Val
 50

In each of the above sequences Σ represent phosphoseryl.

CLAIMS:-

1. An antimicrobial peptide, the peptide being non-glycosylated, less than about 100 amino acids and including an amino acid sequence selected from the group consisting of:-

- 5 AVESTVATLEA Σ PEVIESPPE, (SEQ. ID. NO. 1)
- AVESTVATLED Σ PEVIESPPE, (SEQ. ID. NO. 2)
- AVESTVATLEASPEVIESPPE, (SEQ. ID. NO. 3)
- AVESTVATLEDSPEVIESPPE, (SEQ. ID. NO. 4)
- 10 DMPIQAFLLYQQPVLPVR. (SEQ. ID. NO. 5)

and conservative substitutions therein.

2. An antimicrobial peptide as claimed in claim 1 in which the peptide includes an amino acid sequence selected from the group consisting of:-

- 15 AVESTVATLEA Σ PEVIESPPE, (SEQ. ID. NO. 1)
- AVESTVATLED Σ PEVIESPPE, (SEQ. ID. NO. 2)
- AVESTVATLEASPEVIESPPE, (SEQ. ID. NO. 3)
- AVESTVATLEDSPEVIESPPE, and (SEQ. ID. NO. 4)
- DMPIQAFLLYQQPVLPVR. (SEQ. ID. NO. 5)

3. An antimicrobial peptide as claimed in claim 1 or claim 2 in which the peptide is less than about 70 amino acids.

4. An microbial peptide as claimed in any one of claims 1 to 3 in which the peptide includes an amino acid sequence selected from the group consisting of:-

- MAIPPKKNQDKTEIPTINTIASGEPTSTPTIEAVESTVATLEA Σ PEVIESPPEINT
25 VQVTSTAV; (SEQ. ID. NO. 6)
- MAIPPKKNQDKTEIPTINTIA Σ GEPTSTPTIEAVESTVATLEA Σ PEVIESPPEINT
VQVTSTAV; (SEQ. ID. NO. 7)
- MAIPPKKNQDKTEIPTINTIASGEPTSTPTIEAVESTVATLED Σ PEVIESPPEINT
VQVTSTAV; (SEQ. ID. NO. 8)
- 30 MAIPPKKNQDKTEIPTINTIA Σ GEPTSTPTIEAVESTVATLED Σ PEVIESPPEINT
VQVTSTAV; (SEQ. ID. NO. 9)
- TEIPTINTIASGEPTSTPTIEAVESTVATLEA Σ PEVIESPPEINTVQVTSTAV;
(SEQ. ID. NO. 10)
- TEIPTINTIA Σ GEPTSTPTIEAVESTVATLEA Σ PEVIESPPEINTVQVTSTAV;
35 (SEQ. ID. NO. 11)

TEIPTINTIASGEPTSTPTTEAVESTVATLEDΣPEVIESPPEINTVQVTSTAV;
(SEQ. ID. NO. 12)

TEIPTINTIAΣGEPTSTPTTEAVESTVATLEDΣPEVIESPPEINTVQVTSTAV;
(SEQ. ID. NO. 13)

5 MAIPPKKNQDKTEIPTINTIASGEPTSTPTIEAVESTVATLEASPEVIESPPEINT
VQVTSTAV; (SEQ. ID. NO. 14)
MAIPPKKNQDKTEIPTINTIASGEPTSTPTTEAVESTVATLEDSPPEVIESPPEINT
VQVTSTAV; (SEQ. ID. NO. 15)
TEIPTINTIASGEPTSTPTIEAVESTVATLEASPEVIESPPEINTVQVTSTAV;
10 (SEQ. ID. NO. 16)
TEIPTINTIASGEPTSTPTTEAVESTVATLEDSPPEVIESPPEINTVQVTSTAV;
 (SEQ. ID. NO. 17)

and conservative substitutions therein.

5. An microbial peptide as claimed in any one of claims 1 to 4 in which
the peptide includes an amino acid sequence selected from the group
consisting of:-

MAIPPKKNQDKTEIPTINTIASGEPTSTPTIEAVESTVATLEAΣPEVIESPPEINT
VQVTSTAV; (SEQ. ID. NO. 6)

MAIPPKKNQDKTEIPTINTIAΣGEPTSTPTIEAVESTVATLEAΣPEVIESPPEINT
VQVTSTAV; (SEQ. ID. NO. 7)

MAIPPKKNQDKTEIPTINTIASGEPTSTPTTEAVESTVATLEDΣPEVIESPPEINT
VQVTSTAV; (SEQ. ID. NO. 8)

MAIPPKKNQDKTEIPTINTIAΣGEPTSTPTTEAVESTVATLEDΣPEVIESPPEINT
VQVTSTAV; (SEQ. ID. NO. 9)

20 TEIPTINTIASGEPTSTPTIEAVESTVATLEAΣPEVIESPPEINTVQVTSTAV;
(SEQ. ID. NO. 10)

TEIPTINTIAΣGEPTSTPTIEAVESTVATLEAΣPEVIESPPEINTVQVTSTAV;
(SEQ. ID. NO. 11)

TEIPTINTIASGEPTSTPTTEAVESTVATLEDΣPEVIESPPEINTVQVTSTAV;
30 (SEQ. ID. NO. 12)

TEIPTINTIAΣGEPTSTPTTEAVESTVATLEDΣPEVIESPPEINTVQVTSTAV;
(SEQ. ID. NO. 13)

MAIPPKKNQDKTEIPTINTIASGEPTSTPTIEAVESTVATLEASPEVIESPPEINT
VQVTSTAV; (SEQ. ID. NO. 14)

35 MAIPPKKNQDKTEIPTINTIASGEPTSTPTTEAVESTVATLEDΣPEVIESPPEINT
VQVTSTAV; (SEQ. ID. NO. 15)

TEIPTINTIASGEPTSTPTIEAVESTVATLEASPEVIESPPEINTVQVTSTAV; and
(SEQ. ID. NO. 16)

TEIPTINTIASGEPTSTPTTEAVESTVATLEDSPPEINTVQVTSTAV;
(SEQ. ID. NO. 17)

5 6. An antimicrobial peptide as claimed in any one of claims 1 to 5 in
which the peptide is selected from the group consisting of:-

AVESTVATLEA Σ PEVIESPPE, (SEQ. ID. NO. 1)

AVESTVATLED Σ PEVIESPPE, (SEQ. ID. NO. 2)

AVESTVATLEASPEVIESPPE, (SEQ. ID. NO. 3)

10 AVESTVATLEDSPPEINTVQVTSTAV; (SEQ. ID. NO. 4)

DMPIQAFLLYQQPVLPVR. (SEQ. ID. NO. 5)

MAIPPKKNQDKTEIPTINTIASGEPTSTPTIEAVESTVATLEA Σ PEVIESPPEINT
VQVTSTAV; (SEQ. ID. NO. 6)

15 MAIPPKKNQDKTEIPTINTIA Σ GEPTSTPTIEAVESTVATLEA Σ PEVIESPPEINT
VQVTSTAV; (SEQ. ID. NO. 7)

MAIPPKKNQDKTEIPTINTIASGEPTSTPTTEAVESTVATLED Σ PEVIESPPEINT
VQVTSTAV; (SEQ. ID. NO. 8)

MAIPPKKNQDKTEIPTINTIA Σ GEPTSTPTTEAVESTVATLED Σ PEVIESPPEINT
VQVTSTAV; (SEQ. ID. NO. 9)

20 TEIPTINTIASGEPTSTPTIEAVESTVATLEA Σ PEVIESPPEINTVQVTSTAV;
(SEQ. ID. NO. 10)

TEIPTINTIA Σ GEPTSTPTIEAVESTVATLEA Σ PEVIESPPEINTVQVTSTAV;
(SEQ. ID. NO. 11)

25 TEIPTINTIASGEPTSTPTTEAVESTVATLED Σ PEVIESPPEINTVQVTSTAV;
(SEQ. ID. NO. 12)

TEIPTINTIA Σ GEPTSTPTTEAVESTVATLED Σ PEVIESPPEINTVQVTSTAV;
(SEQ. ID. NO. 13)

MAIPPKKNQDKTEIPTINTIASGEPTSTPTIEAVESTVATLEASPEVIESPPEINT
VQVTSTAV; (SEQ. ID. NO. 14)

30 MAIPPKKNQDKTEIPTINTIASGEPTSTPTTEAVESTVATLEDSPPEINTVQVTSTAV;
VQVTSTAV; (SEQ. ID. NO. 15)

TEIPTINTIASGEPTSTPTIEAVESTVATLEASPEVIESPPEINTVQVTSTAV; and
(SEQ. ID. NO. 16)

TEIPTINTIASGEPTSTPTTEAVESTVATLEDSPPEINTVQVTSTAV;
(SEQ. ID. NO. 17)

7. A chimeric compound, the compound including the peptide as claimed in any one of claims 1 to 6 conjugated to a non-peptide molecule.
8. A chimeric compound as claimed in claim 7 in which the non-peptide portion of the molecule includes acyl groups.
- 5 9. An antimicrobial composition, the composition including the peptide as claimed in any one of claims 1 to 6 and an acceptable carrier.
10. A method of treating or preventing dental caries or periodontal disease in a subject, the method comprising the step of administering a peptide as claimed in any one of claims 1 to 6 or the composition as claimed in claim 9 to the teeth or gums of the subject in need of such treatments.

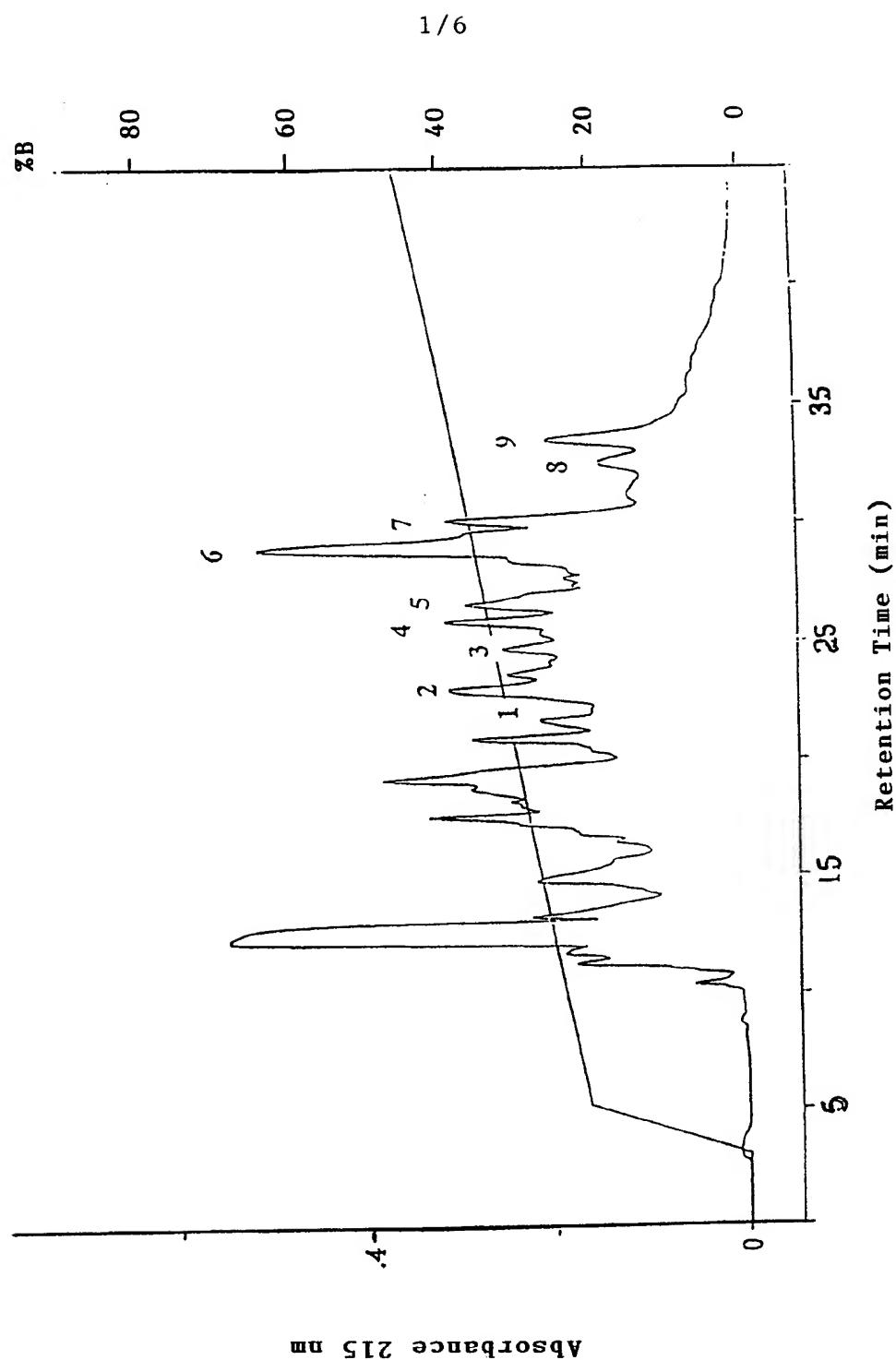


Figure 1

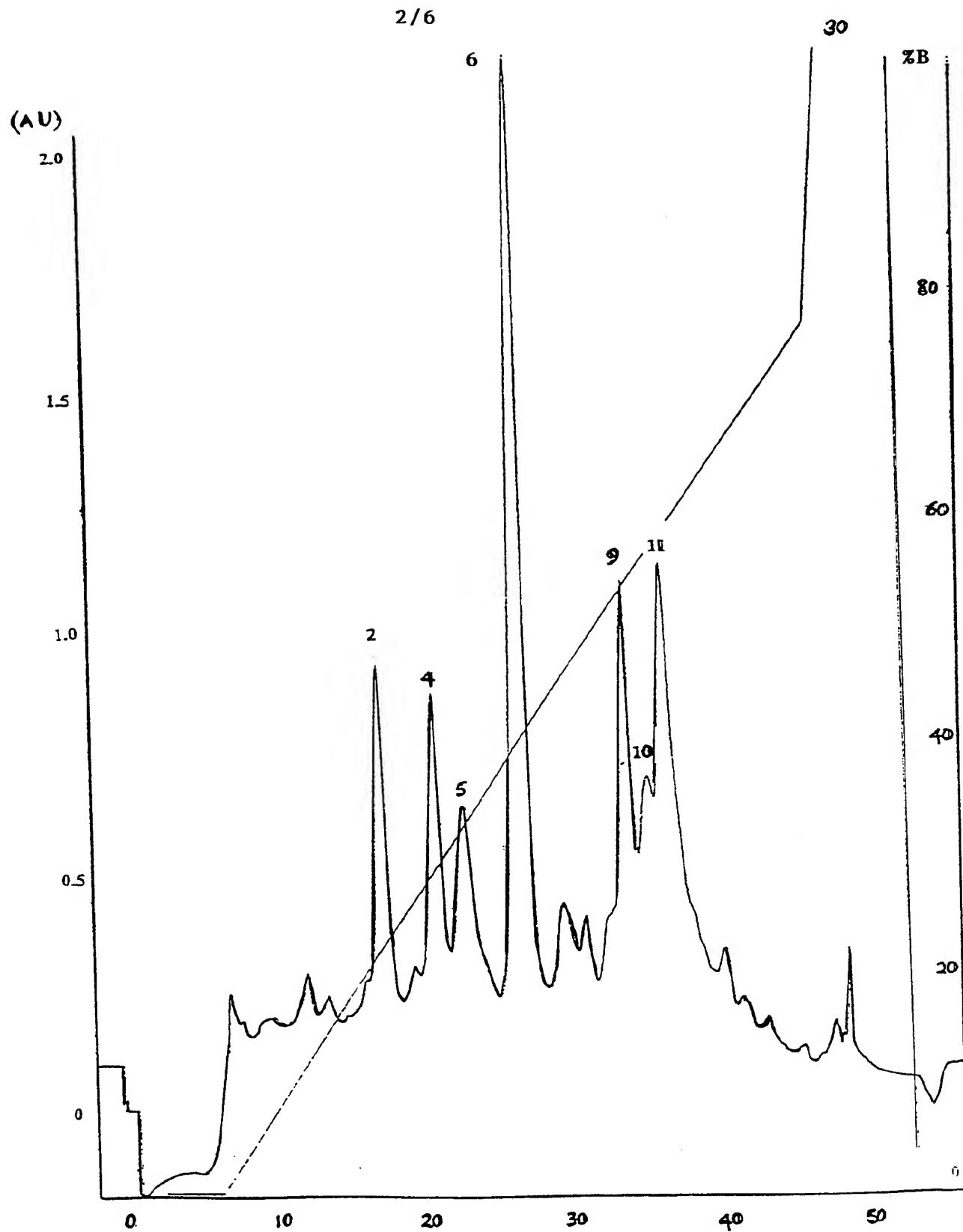
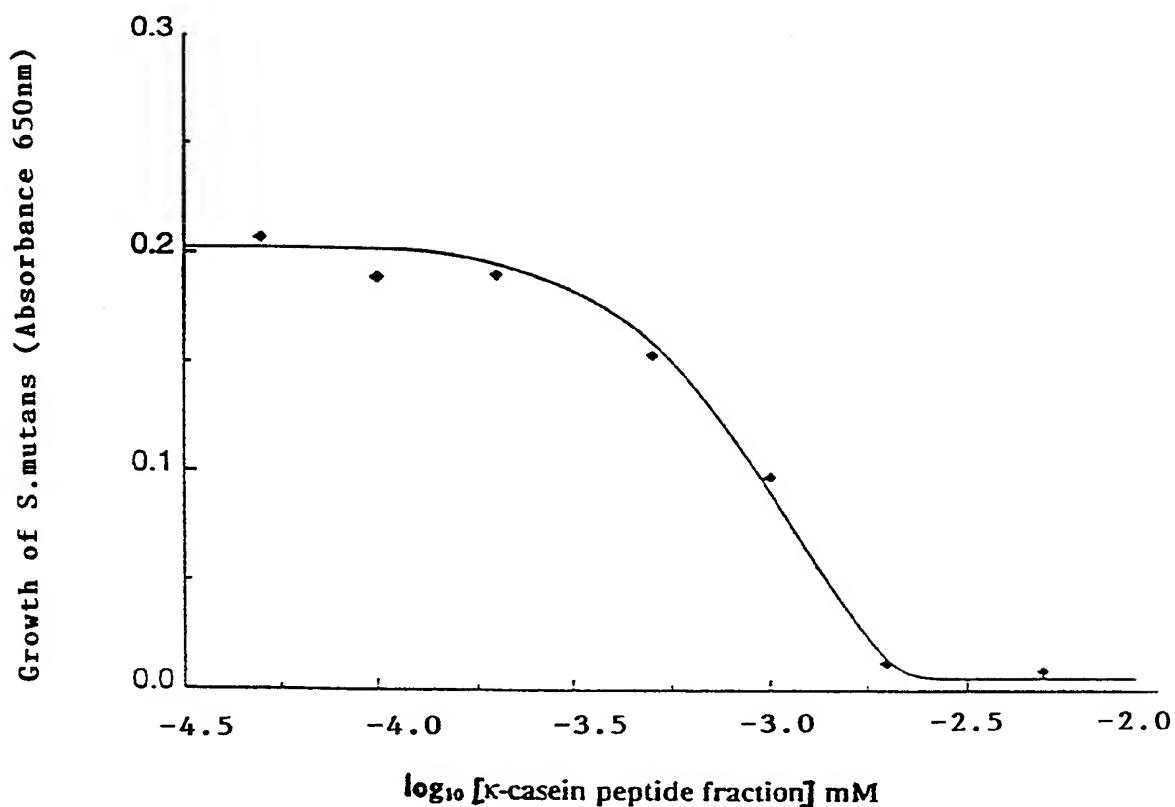


FIGURE 2

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**Figure 3**

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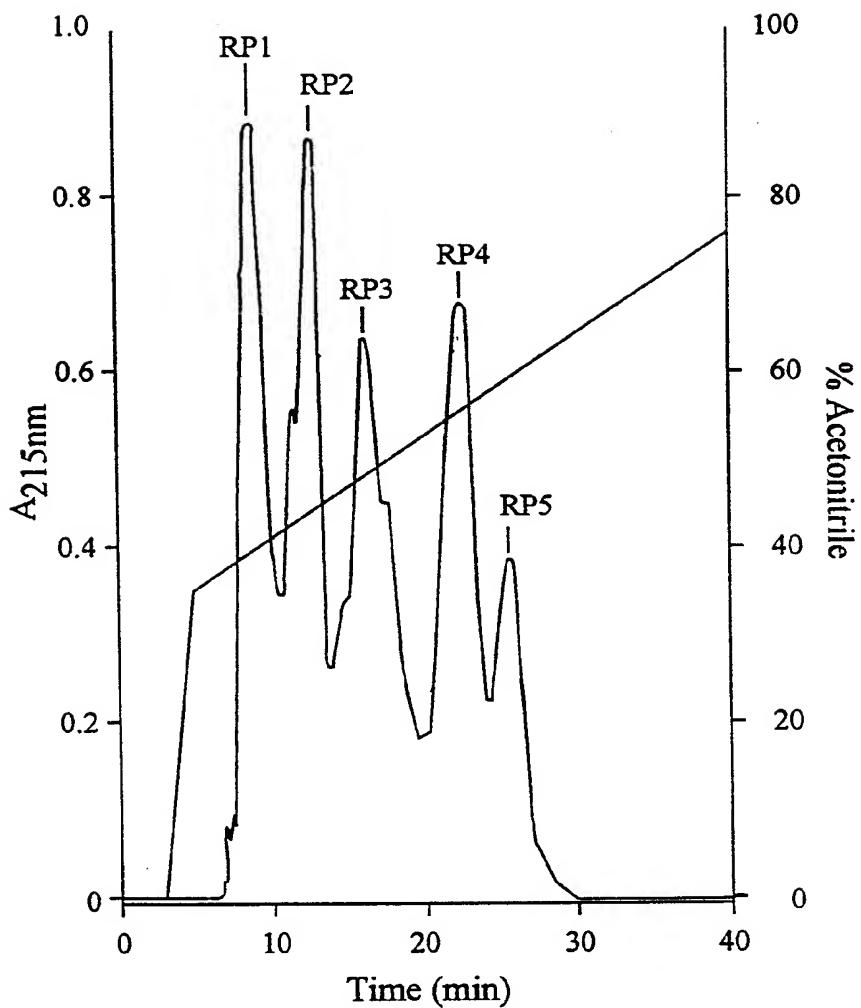


Figure 4

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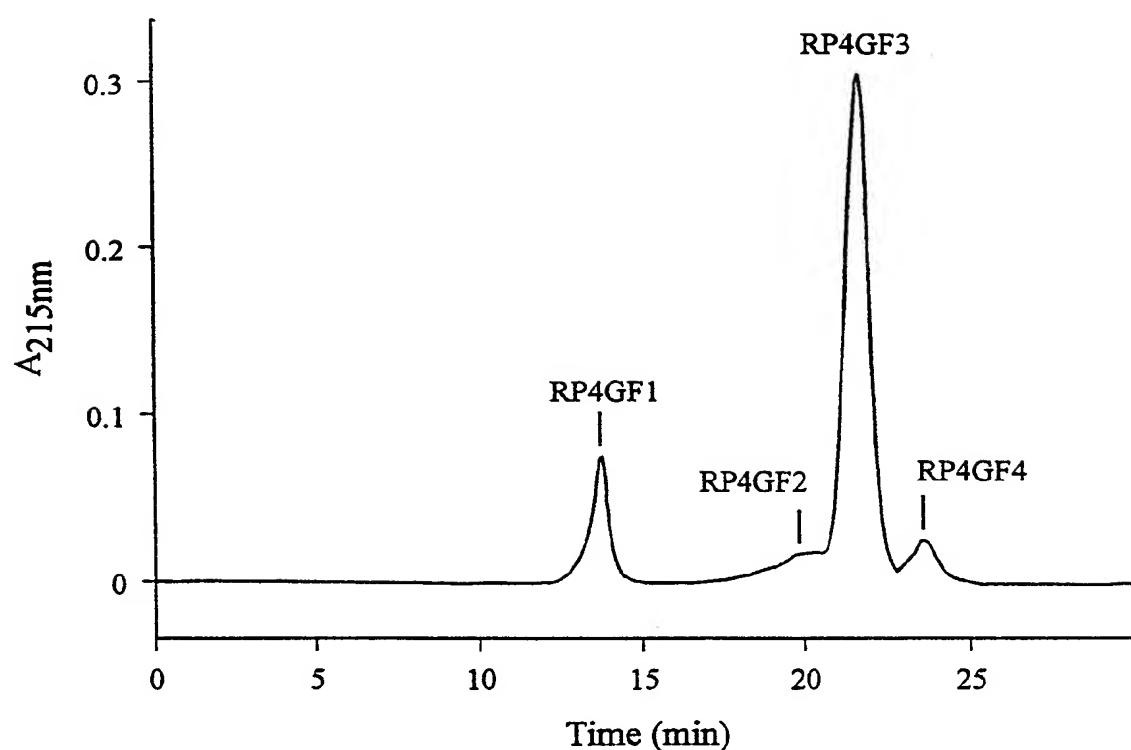
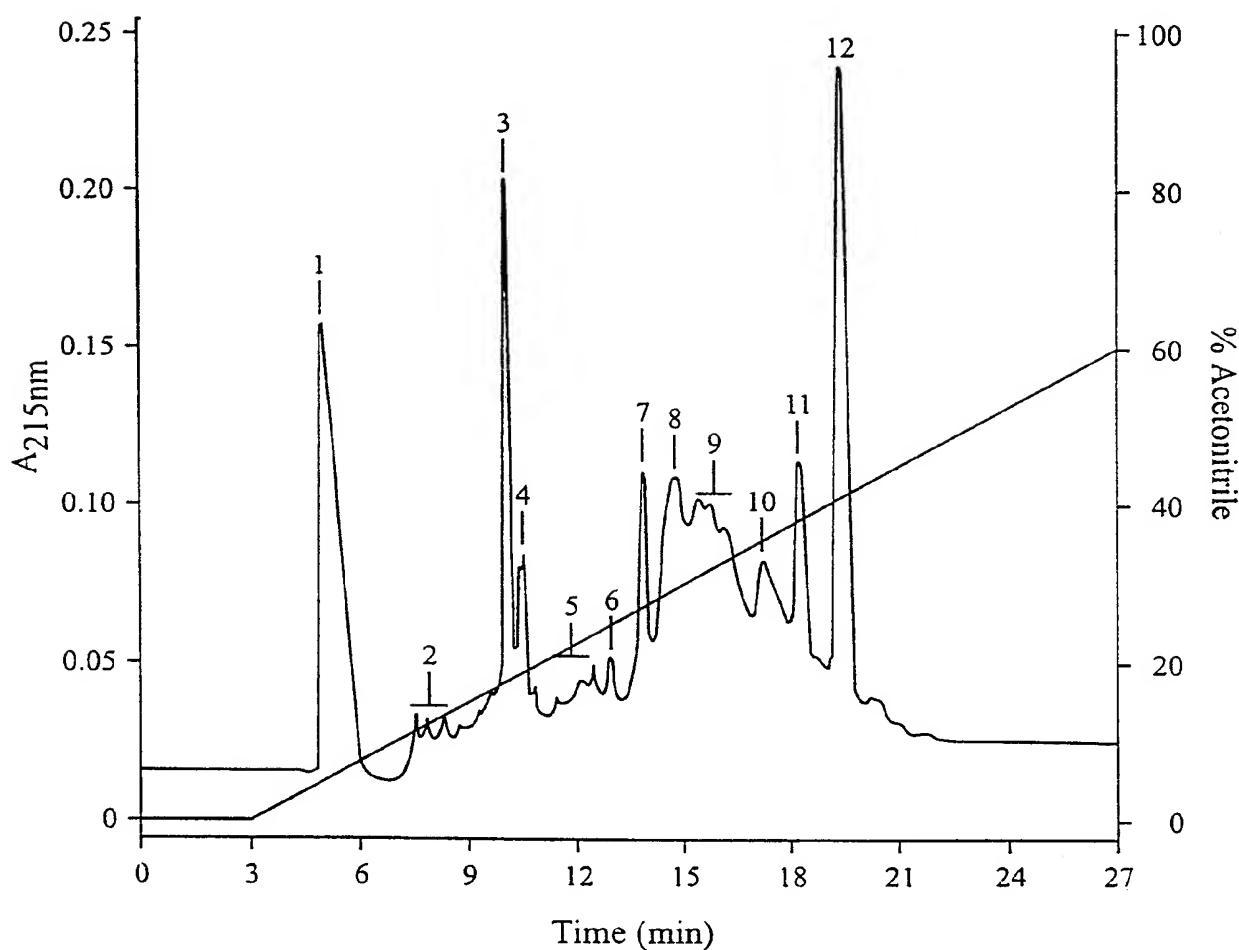


Figure 5

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**Figure 6**

INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU 98/00972

A. CLASSIFICATION OF SUBJECT MATTERInt Cl⁶: C07K 14/47, A61K 7/16, 7/18, 9/68, 38/17

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

STN - subsequence search AVEST VATLE[AD]X PEVIE SPPE &
DMPIQAFLLYQQPVVLGPVR.

Medline - keywords: kappa and casein

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	Chemical Abstracts 110:22025 & Agric. Biol Chem (1988) 52 (10) 2577-81 "Preparation of anti-bovine beta-casein monoclonal antibody and analysis of the interaction between the antibody and beta-casein fragment" Nagaune, S. et al. See Registry No. 118060-89-2	1, 2, 3
X	Chemical Abstracts 111: 132793 & Milchwissenschaft (1988), 43(11), 705-7. "The common antigenic site of Bovine and Human beta-caseins." Otani, H. et al See Registry No: 122390-83-4	1, 2

 Further documents are listed in the continuation of Box C See patent family annex

* Special categories of cited documents:

- "A" Document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier application or patent but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

- "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search

10 December 1998

Date of mailing of the international search report

22 DEC 1998

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU 98/00972

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	Chemical Abstracts 108:51720 & Daiichi Yakka Daigaku Kenkyu Nenpo (1986), 17, 29-40 "Turbidity of stem bromelain toward casein soln". Ota, S. et al. See Registry No 112353-19-2	1, 2
X	Chemical Abstracts 106:150509 & Biochem Biophys. Res. Commun (1987), 142(2), 617-21 "Cloning and sequence analysis of bovine beta-casein cDNA" Jimenez-Flores, R. et al See Registry numbers 107606-21-3 and 107606-20-2	1, 2
X	Chemical abstracts 77:2143 & Eur. J. Biochem (1972) 26(3), 328-37 "Characterisation of the genetic variants of bovine. Alpha S1 and beta. Casein" Grosclaude, F. et al. See Registry numbers 37240-07-6, 37240-06-5 and 37240-05-4.	1, 2
X	Biochimie 1977, 59, No. 4. Pages 375-379 'Primary Structure of the Casein...' ADDEO, F. et al. See page 377 'Zébu' sequence positions $\alpha\alpha$ 138 - $\alpha\alpha$ 158	1, 2 4, 5, 6 9
Y	US 4992420 (12 February 1991) Neeser, J. 'Dental Antiplaque and anti-caries Agent'. See whole document	9, 10
A	DNA Sequence-J. DNA Sequencing and Mapping Vol. 3 pp245-246 "Cloning and sequencing of human k-casein DNA" (See page 245 column 2 lines 12-14)	1-6
Y	Journal of Chromatography 646 (1993) pages 391-396 'The analysis of multiple phosphoseryl-containing cascin peptides using capillary zone electrophoresis' Adamson, N. et al. (See in particular introduction)	10
A	WO 87/07615 (17 December 1987) The University of Melbourne et al 'Phosphopeptides'	1-10

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/AU 98/00972

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report				Patent Family Member				
US	4992420	CH	671879	EP	283675	FI	880464	
		JP	63233911	NZ	223400	US	4994441	
		ZA	8800798					
WO	8707615	AU	75483/87	BR	8707352	CA	1315480	
		DK	703/88	EP	268663	FI	880629	
		FI	931988	HU	47309	MC	1862	
		NO	880589	NZ	220673	US	5015628	
END OF ANNEX								